The Weatherization Standards and Field Guide for Pennsylvania is designed to provide direction and guidance to staff and management of the Commonwealth of Pennsylvania’s Weatherization Assistance Program (PAWAP). The program administrator, Department of Community and Economic Development (DCED) provides these standards and field guide for use by its weatherization agencies and private contractors. This manual results from a partnership between DCED, the US Department of Energy Weatherization Assistance Program (DOEWAP), and Saturn Resource Management Inc.

The first chapter, titled Pennsylvania Weatherization Standards outlines the DCED technical program requirements for Pennsylvania’s weatherization agencies. The subsequent chapters comprise the Field Guide and covers suggested technical procedures and standards for energy auditors and technicians.

Weatherization is a collection of procedures designed to reduce energy consumption, increase comfort, improve durability, and enhance health and safety for its clients. Weatherization expenditures are justified primarily by money saved by low-income families in energy expenses. The Department of Energy and State Governments issue requirements for how to spend tax dollars on weatherization cost-effectively. PAWAP now uses priority lists for ensuring the cost-effectiveness of weatherization. These priority lists, presented in the first chapter, were generated by computer analysis of typical Pennsylvania homes, using the National Home Energy Audit (NEAT) and the Manufactured House Energy Audit (MHEA).

This guidebook is designed to be a changeable and constantly improving document. Your comments, questions, and constructive criticism will be important to its future.
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PA WEATHERIZATION STANDARDS

The purpose of this chapter of the Weatherization Standards and Field Guide for Pennsylvania is to summarize the standards necessary for a local weatherization agency to correctly execute the Pennsylvania State Weatherization Plan. The state plan is an agreement among the United States Department of Energy (DOE), PA (DCED), and the local weatherization agencies. Standards are guidance to agency management about the minimum technical program requirements of the PAWAP and are confined to the first chapter. The remainder of the book is devoted to procedures, to be used by agency subcontractors and energy auditors in executing field based weatherization activities.

GENERAL STANDARDS

The purpose of general standards is to standardize the provision of services and the documentation that provides proof that funds were spent according to good practice.

Materials for Measures

Weatherization materials, installed under the PAWAP, must conform to the specifications and standards as referenced in Appendix A of 10 CFR, Part 440. Installation of all materials must be in a professional and workmanlike manner according to industry accepted practices or manufacturer specifications.

Insulation may only be purchased from companies who are on the DCED list of approved manufacturers.

Energy Audit

Each dwelling must receive a site-specific energy audit, following the approved Weatherization Priority Lists. Measures that have been identified in the priority list have been proven to have a savings-to-investment ratio (SIR) greater than one (1). The installa-
tion of these measures is considered adequate weatherization practice.

Each energy audit will include a blower-door test, a heating-system assessment, a baseload audit, a health-and-safety evaluation and recommended building shell air sealing and insulation retrofits.

In the process of conducting an audit, the auditor should make every attempt to determine how the home is being used and define the actual thermal boundary. The thermal boundary is made up of all the surface or building components that separate heated from unheated spaces. An example would be an attic staircase where the sidewalls, staircase ceiling, and door are part of the thermal boundary. For additional guidance see “Air-Sealing and Insulating” on page 161.

Document the energy audit in the client file. At a minimum, the client file must include the required information on the DCED-approved audit protocol. Digital photographs needed to justify work scope are required.

**Client Education**

Clients can enhance weatherization efforts by developing good habits for using energy wisely. Client education must be provided to every client as part of weatherization services. See “Client education” on page 42.

**Air-Leakage Testing**

All dwelling units must have blower door tests performed before, during, and after a weatherization retrofit. Its purpose is to help locate air leakage and to monitor the level of air tightness resulting from air sealing and insulating the building shell.

The minimum blower door generated value to be obtained and documented in the client file is air flow in cubic feet of air per minute at a house pressure difference of 50 pascals (cfm50).
A blower door test is required for estimating air flow (cfm50). These may be obtained from the blower door gauges, manufacturer provided calibration charts (CRF-50) or software.

Technicians may perform as many blower door tests as they feel necessary to monitor the progress of their air sealing work. This is recommended. **However, the auditor must perform and document a minimum of one “Pre Test” and one “Post Test” in the client file.** On rare occasions a blower door test may not be possible. Documentation of the reasons why a blower door test was not performed must be provided in the client file.

### Zonal Pressure Diagnostics and Pressure Pan Testing

Other types of blower door techniques such as zonal pressure diagnostics to detect air leakage pathways and pressure-pan testing to help find duct leakage are used to detect hidden air leaks quickly.

Zonal Pressure Diagnostics on all homes and Pressure Pan Testing on warm air systems are required as routine test procedures. These tests should be repeated in cases where post blower door test results show less than expected air leakage reductions and further investigation by using these procedures is necessary.

Zonal tests may be performed on interior wall cavities, tuck under garage ceilings, cantilevered ceilings, knee wall attics, vented crawl spaces etc. Where applicable, agencies should perform zonal tests on the basement and attic spaces.

The necessary equipment to perform these tests include the blower door, digital manometer, smoke generating device and pressure pan. Agencies must have this equipment available to be able to perform these tests when necessary. See “Using a manometer to test air barriers” on page 215. See “Pressure-pan testing” on page 221.
Priority Lists for Measure Selection

A priority list for measure selection must be used to select measures to install in homes. The priority lists are based on the National Home Energy Audit (NEAT) and the manufactured House Energy Audit (MHEA), which are accepted methods of determining the cost-effectiveness of weatherization measures. The Single-Family Home Measure Selection Priority List dictates measure selection in single-family homes. The Manufactured house Measure Selection Priority List dictates measure selection for manufactured houses. In both priority lists, measures contained within the categories of building shell, mechanical and baseload retrofits are listed in order of priority, according to their cost-effectiveness.

Weatherization agencies must install measures higher on the list before measures lower on the list. The procedure is to budget funds for as many high-priority measures as possible, working from the top of the list to the bottom. Not following the Priority List measures is unacceptable, except when serious unsolvable problems prevent their installation. Serious unsolvable problems are health, safety, and building-durability problems that cannot be solved within the scope of weatherization.

Agencies must develop in-house technical know how, and purchase the proper equipment to be able to effectively install measures such as dense pack insulation in areas such as wooden framed sidewalls or manufactured house bellies and ceilings.
### Health and Safety

Repair or Replace Furnace as per Health & Safety protocols in PA WX Standards and Field Guide

### Building Shell Retrofits

Air Seal as per blower door guided protocols  
Duct Sealing as per blower door guided or duct diagnostic protocols

<table>
<thead>
<tr>
<th>Insulation Component</th>
<th>Measure (no existing insulation, unless specified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ducts (in uncond. spaces)</td>
<td>Add R-11 wrap</td>
</tr>
<tr>
<td>Open Attic Ceilings</td>
<td>Add R-38</td>
</tr>
<tr>
<td>Kneewall (in finished attic)</td>
<td>Add R-11-13 batt or fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof Rafter (in finished attics)</td>
<td>Add batts or fill cavity where dimensions allow up to 12 inches in depth</td>
</tr>
<tr>
<td>Closed Wall Cavities (adjacent to uncond. spaces)</td>
<td>Fill to 3.5 lbs/cu.ft. with loose fill insulation where dimensions will allow</td>
</tr>
<tr>
<td>Open Wall Cavities (adjacent to uncond. spaces)</td>
<td>Add R-15 batt and cover with air barrier</td>
</tr>
<tr>
<td>Closed Floor Cavities (adjacent to uncond. spaces)</td>
<td>Fill to 3.5 lbs/cu.ft. with loose fill insulation</td>
</tr>
<tr>
<td>Open Floor Cavities (uncond. basements and crawl spaces)</td>
<td>Add R-19 batt</td>
</tr>
<tr>
<td>Closed Ceiling Cavities (adjacent to uncond. spaces)</td>
<td>Fill cavity where dimensions allow up to 12” in depth</td>
</tr>
<tr>
<td>Sill Box (rim joist) (conditioned basements)</td>
<td>Add R-11 polystyrene and seal (optional: Two-part closed-cell foam to air seal and insulate to R-11)</td>
</tr>
<tr>
<td>Open attic ceilings</td>
<td><strong>Existing:</strong> R-11; Add R-30</td>
</tr>
<tr>
<td>Open attic ceilings</td>
<td><strong>Existing:</strong> R-19; Add R-19</td>
</tr>
</tbody>
</table>

### Low-E Storm Windows

- Single pane window with no storm  
  Install low-e storm window (glass emissivity ($\varepsilon$) $\leq 0.22$)
- Metal-framed dual pane clear window  
  Install low-e storm window ($\varepsilon \leq 0.22$)
- Single pane window/ deteriorated clear storm  
  Replace existing clear storm window low-e storm window ($\varepsilon \leq 0.22$)

### BaseLoad Measures

- **Lighting**  
  Replace incandescent and halogen lamps with CFL lamps as per PA WX Standards and Field Guide
- **Domestic Hot Water Measures**  
  Add R-11 wrap, pipe insulation and other water heating measures where manufacturer specs allow and as per PA WX Standards and Field Guide
- **Refrigerator Replacement**  
  Replace as per PA WX Standards, using WAPTAC tool
MECHANICAL RETROFITS

Install automatic setback thermostat with double setback if possible
Repair or replace as per efficiency protocols in PA WX Standards and Field Guides
Use 90+, if cost effective to replace and structurally possible

WINDOWS AND DOORS

| Missing or deteriorated windows beyond repair | Replace windows with RS labeled windows ($U \leq 0.22$ operable windows, $U \leq 0.20$ fixed windows) |
| Missing or deteriorated doors beyond repair | Replace with solid core or insulated doors |
### MANUFACTURED HOUSE SHELL AND DUCT RETROFITS

Air Seal as per blower door guided protocols and targeted air leakage reductions. Duct Sealing as per blower door guided and duct diagnostic protocols.

<table>
<thead>
<tr>
<th>Insulation Components</th>
<th>Existing Condition</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall System (fiberglass batts or loose fill fiberglass only)</td>
<td>No insulation</td>
<td>Add R-11-13 batts or fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof System (loose fill fiberglass only)</td>
<td>No insulation</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Floor System (loose fill fiberglass only)</td>
<td>No insulation</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Floor System (loose fill fiberglass only)</td>
<td>1.5” insulation</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Floor System (loose fill fiberglass only)</td>
<td>2” insulation</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof System (loose fill fiberglass only)</td>
<td>1” foam core</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof System (loose fill fiberglass only)</td>
<td>1.5” foam core</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof System (loose fill fiberglass only)</td>
<td>3.5” insulation</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Wall System (fiberglass batts or loose fill fiberglass only)</td>
<td>1.5” insulation</td>
<td>Add R-11-13 batts or fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof System (loose fill fiberglass only)</td>
<td>1” foam +1.5”</td>
<td>Fill cavity where dimensions allow</td>
</tr>
<tr>
<td>Roof System (loose fill fiberglass only)</td>
<td>1” foam +2” foam</td>
<td>Fill cavity where dimensions allow</td>
</tr>
</tbody>
</table>

### BASELOAD MEASURES

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>Replace incandescent and halogen lamps with CFL lamps as per PA WX Standards and Field Guide</td>
</tr>
<tr>
<td>Domestic Hot Water Measures</td>
<td>Add R-11 wrap, pipe insulation and other water heating measures where manufacturer specs allow and as per PA WX Standards and Field Guide</td>
</tr>
<tr>
<td>Refrigerator Replacement</td>
<td>Replace as per PA WX Standards using WAPTAC tool</td>
</tr>
</tbody>
</table>

### MECHANICAL RETROFITS

Install automatic setback thermostat with double setback if possible. Repair or replace as per Health and Safety and efficiency protocols in PA WX Standards and Field Guides. If cost effective to replace, use 90+ unless structurally impossible.

### WINDOWS AND DOORS

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing or deteriorated window units beyond repair</td>
<td>Replace with Energy Star Labeled slider or double hung units and self-storing storm windows</td>
</tr>
<tr>
<td>Deteriorated doors beyond repair</td>
<td>Replace with factory replacement types</td>
</tr>
</tbody>
</table>
SINGLE FAMILY HOME STANDARDS

Agencies should develop the ability through their own employees or through competent contractors to perform air-sealing and insulating procedures outlined in the Field Guide. Prioritize measures according to the “PA WAP Single Family Homes Measure Selection Priority List”. For additional guidance see “Air-Sealing and Insulating” on page 161. Moisture issues must be addressed and resolved before air sealing and insulating.

Conditioned Versus Unconditioned Basements

Determining which weatherization measures to apply in foundation spaces depends on whether it is conditioned or unconditioned. Some general guidelines to assist the auditor are as follows:

Conditioned Basement

- Relatively tight or unvented foundation.
- Living space.
- Intentional or unintentional heat delivered to the space.

If you determine that a foundation space is conditioned, air-seal exposed foundation walls or framing, and insulate the band joist. See “Rim insulation and air-sealing” on page 194.

Unconditioned Basement or Crawl Space

- Leaky, vented or severely degraded foundation.
- Not a living space.
- No heat delivered.

If unconditioned, air-seal and insulate the floor cavity between the basement and first floor. In both cases, seal all air pathways between the basement or crawl space and the house. See “Floor insulation” on page 195.
Closed Cavity Dense Pack Insulation

Insulate above-grade exterior wall cavities in frame dwellings with dense-packed blown-in insulation where no insulation exists. Use the fill-tube method to ensure complete coverage and acceptable density. Wall insulation is an important and effective retrofit and weatherization agency crews and contractors should obtain whatever tools, equipment, and training they need to perform this retrofit confidently.

Fill other types of closed cavities with dense-packed insulation in areas such as floored attics, cantilevered ceilings, tuck under garage ceilings, manufactured house floors, and manufactured house roof cavities. Use fiberglass instead of cellulose anywhere moisture may be a problem. Choose fiberglass for manufactured houses because it puts less pressure on cavities during installation. Cellulose's acidic fire retardant may corrode manufactured house metal roofing and siding. See “Air-Sealing and Insulating” on page 161. See “Manufactured Housing Specifications” on page 227.

Window and Door Replacement

Window and door replacements do not have an acceptable SIR on single family homes or manufactured houses. Window and door replacement shall not be performed instead of cost-effective weatherization measures on the priority list. Replacing broken glass or other repairs are acceptable treatments. Window replacement or door replacement is not an air sealing measure.

Window and door replacements should only be considered under the following circumstances.

- Higher priority weatherization measures will all be completed within the home’s weatherization budget.
- The existing window or door creates a hazard to the health, safety, and/or building durability.
• Existing window or door is damaged or weathered beyond repair, and a replacement option would be less expensive than the repair.

**MANUFACTURED HOUSE STANDARDS**

Agencies should develop the ability through their own employees or through competent contractors to perform air-sealing and insulating procedures outlined in this field guide. Prioritize measures according to the “PA WAP Manufactured Home, Measure Selection Priority List (MHEA)” on page 19.

In addition to following the priority list and guidance in the chapter on Manufactured House Standards, the following standards also apply to manufactured houses.

• Install a ground vapor barrier in all cases except where there are severe obstructions or evidence of water ponding underneath the home.

• Install blown-in fiberglass insulation only in belly, wall and ceiling cavities.

• Verify the serviceability of existing ventilation fans or install new ventilation fans where none exist.

• Install only heating appliances, windows and doors that are designed for manufactured houses.

• If replacing windows purchase units with self storing storm windows.

• Coat roof seams and edges if the roof has been accessed for activities such as insulation or replacement of a chimney cap.

• Verify that clothes dryers are vented to the outside of the crawl space.

For additional guidance See “Manufactured Housing Specifications” on page 227.
Building Repairs

Home repairs to siding or roofing, painting, structural components for the purpose of protecting weatherization measures are allowable expenditures. Repair items include but are not necessarily limited to the following items.

- Minor roof repair including roof leaks, flashings, gutters and downspouts.
- Repair plumbing leaks.
- Minor structural repairs such as reinforcing dropped ceilings, floor repair, etc.

Heating-System Standards

The goal of heating-system service, provided during weatherization, is to make systems safer, more efficient, and to preserve them. To accomplish these goals, weatherization agencies or their sub contractors perform some of these services.

- Cleaning and tuning of gas and oil burners.
- Replacement of conventional oil burners with flame-retention-head burners on boilers only. Unit should have additional expected life of 15 years.
- Replacement of unsafe or inefficient heating units with high-efficiency units.
- Improving distribution systems on forced air, hot water and steam systems.

See “Heating System Specifications” on page 87.

Heating Systems Testing

Appliances used to heat homes and heat water for domestic use should operate safely and efficiently. All vented space-heating and water-heating appliances must be visually inspected and tested, using a combustion analyzer. Correct any safety problems before
weatherization is completed. Document any preexisting safety issues for both standard weatherization and Crisis programs.

Inspect all operating units for obvious venting defects. Gas supply lines should be tested for fuel leaks, and clearances to combustibles checked. Report any deficiencies concerning these units to the building occupant and owner in writing. With the exception of assuring chimney safety, no combustion analysis should be performed on coal- or wood-burning appliances. See “Combustion safety and efficiency testing” on page 88.

**Chimney Safety**

Assessing chimney safety and making chimney repairs are some of the most important measures to insure home health and safety. Categories of venting improvements include the following items.

- Clearing obstructions from chimneys and flues.
- Replacement of corroded, poorly designed, or illegal, vent connectors.
- Fan assisted sidewall venting.
- Relining chimneys.
- Replacement of non-vented space heaters with vented units.

See “Venting combustion gases” on page 109.

**Worst Case Chimney Safety Testing**

Depressurization, blocked chimneys, and installation flaws are leading causes of back drafting and spillage. All homes must have a worst-case depressurization and draft test after all weatherization work has been performed. Its purpose is to insure that all vented combustion appliances have adequate chimney draft. The test can isolate sources of depressurization which may include exhaust fans, return ducts, the furnace blower, and chimneys themselves. The test may be performed by either the
field technician or by the final inspector upon completion of weatherization and must be documented. See “CAZ Combustion Safety Test” on page 103. and See “Improving inadequate draft” on page 108.

**Duct Induced Pressures**

Other types of testing on forced air systems can help diagnose comfort and infiltration related problems caused by unbalanced forced air systems. See “Duct-induced pressures” on page 223.

**Unvented Space Heaters**

Unvented space heaters are particularly dangerous heating devices, known to cause high levels of moisture and carbon monoxide. Unvented space heaters may not be used as a primary heat source. They may only be used as a secondary or emergency heat source. Refer to DCED Directive.

Vented space heaters may be installed to replace unvented space heaters when used as a primary heat source. In this case, the unvented space heater must be removed from the premises and destroyed. See “Venting combustion gases” on page 109.

**Combustion Air**

Assure that all fossil-fuel-fired heating systems have an adequate source of combustion air. See “Combustion air” on page 126.

**Replacement Heating Units**

Don’t assume that older furnaces and boilers are unsafe or inefficient until testing them. During testing, make appropriate efforts to repair and adjust the existing furnace or boiler, before deciding to replace it. Most replacement parts are commonly available.

Heating appliances are often replaced when the cost of repairs and retrofits exceeds one half of estimated replacement costs. Estimate the repair and retrofit costs and compare them to replacement cost before deciding between retrofit and replacement. Replace the heating unit that meets one or more of these conditions.
• A furnace that has a cracked heat exchanger.
• A boiler that has a leaking heat exchanger.
• The furnace cabinet and a majority of other critical components are corroded or deemed beyond repair.
• A standard tune-up will not bring the heating unit in line with minimum health, safety or efficiency standards set forth in “Combustion Standards for Gas Furnaces” on page 91 and “Combustion Standards for Oil-Burning Appliances” on page 96.

**Document the reasons for replacement.**

When a heating unit is replaced, the weatherization agency is responsible for assuring that an accurate heat loss calculation is performed on the house for the purpose matching the heating units output with the heat-loss rate of the house. This calculation must use the “Manual J” protocol and should take into account any weatherization work that is planned for the building. Sizing considerations should be 100% of the calculated heating load for the structure. Document this calculation in the client file.

**BASELOAD ENERGY STANDARDS**

The energy used by electric or gas appliances in a home that is not used for space conditioning is referred to as *baseload energy use*. The following measures are approved as qualifying baseload measures for PAWAP.

**Refrigerator Replacement**

Evaluate the home’s primary refrigerator. The primary refrigerator may be replaced if an SIR of 1 or greater is obtained using the WAPTAC Refrigerator Replacement Tool.

See “Refrigerator Replacement” on page 50.
Refrigerator Maintenance
- Test and adjust temperature (optimal freezer 0º - 5º, optimal fresh food 36º-40º).
- Energy Education.

Lighting
- CFL replacement of incandescent bulbs used 2 hours per day or more including outside and halogen torchieres.

Clothes Dryer Improvements
- Replacement of flex duct with smooth metal pipe.
- Energy Education.

Water Heating
- Replace water heaters that are unsafe or leaking.
- Standard hot water conservation measures.

Administrative Issues
All baseload measure justifications must be documented in the client file on DCED approved forms.

Incorporating Baseload Measures into Job Costs
The intent of incorporating baseload measures into the program is to enhance the opportunity for energy savings for particular dwelling units.

The mission of the program is to identify the combination of measures including shell, mechanical and baseload measures that will provide the greatest savings for a particular unit. Baseload measures are to be incorporated into average Weatherization job costs. The benefit of adding baseload measures to Weatherization will be especially apparent in homes that have high baseload consumption and moderate heating consumption. Auditors will have a
wider array of choices to target Weatherization dollars for greatest impact. This is intended not only to provide for greater overall energy savings but also to provide energy savings opportunities for a larger number of low-income households.

When screening clients for weatherization eligibility it is suggested that agencies determine if clients have already participated in utility baseload programs. If they have not and are eligible, agencies may elect to coordinate baseload referrals and/or service delivery with client’s electric utility. In this way, baseload dollars from State funded weatherization can be targeted to non-eligible electric customers with rural electric cooperatives and municipal providers.

Access to clients’ electric and fuel bills will be helpful for the auditor to determine the greatest potential for savings in the home. If this information is not gathered for client’s file, the auditor may request that the client has energy bill or records available to evaluate baseload use during the audit.

See “Assessing baseload energy-saving opportunities” on page 49.

**HEALTH AND SAFETY STANDARDS**

The Department of Energy’s Weatherization Assistance Program allows expenditure of its funds to address and mitigate health and safety hazards associated with weatherization.

**Crew or Contractor Health and Safety**

Every weatherization agency and contractor must have a written health and safety plan for workers, according to the Occupational Safety and Health Administration (OSHA). Every employee should be trained on safety and should understand the most statistically dangerous hazards present at their workplace. Employees should know how to avoid these dangerous hazards. Agencies and contractors must conduct regular safety meetings and encourage workers to report unsafe conditions.
Agencies or contractors, who currently lack a written health and safety plan, are encouraged to use the information in “Worker health and safety” on page 77 as their health and safety plan. Using this information requires a commitment to worker health and safety, extending from management down to each and every employee.

Client Health and Safety

Weatherization must be provided in a manner that minimizes risks to clients. The Weatherization Assistance Program can’t provide solutions for all health and safety issues. Awareness of potential hazards is essential to providing quality weatherization services. Therefore, each dwelling must be individually assessed to determine the existence of potential hazards to workers and clients.

The Agency should make every attempt to solve health and safety problems using a $300 repair allowance and the $300 health and safety allowance. If $600 is inadequate, DCED may, at their discretion, grant permission to exceed the repair and health and safety allowances. The exception to this guideline are heating appliance replacements due to cracked heat exchangers or unserviceable heating units. Housing funds from U.S. Department of Housing and Urban Development, U.S. Department of Health and Human Services, U.S. Department of Agriculture, and local organizations should be used to solve more expensive health and safety problems.

Local agencies and their representatives are to take reasonable precautions against performing work on dwellings, where that work will expose clients to health and safety risks.

In cases where work activities would constitute a health and safety hazard, action is required to limit or avoid particular measure(s), which may exacerbate a health or safety problem. See “Client health and safety” on page 63.
Moisture Problems

Air-sealing work may not be performed on a home that exhibits evidence of extreme moisture problems. Moisture problems must be resolved before beginning air sealing activities. Evidence of moisture problems includes, but is not limited to, the following:

- Evidence of significant bulk moisture entering the building.
- Significant amount of water in basements or crawl spaces.
- Rotted or moldy roof sheathing.
- Significant mold present on interior building surfaces.
- Significant condensation on interior building surfaces such as windows.

See “Symptoms of moisture problems” on page 70.

Moisture abatement may include but is not limited to the following.

- Installation of a ground moisture barrier.
- Control ground-source moisture problems by improving grading, drainage.
- Installation or repair of a gutter or downspout.
- Installation or repair of the exhaust ventilation.
- Installation or replacement of a sump pump.

Clients should also be encouraged to take an active role in resolving moisture problems on their own before weatherization work may begin by performing activities such as unclogging a plugged drain or removal of moisture absorbing or unsanitary materials. See “Solutions to moisture problems” on page 74.

Mold

Risk assessment, abatement, hazard control or removal of mold is not an allowable activity under the DOE Weatherization Pro-
gram. However, work that is needed to prevent mold is allowable. Measures described under “Moisture Problems”, “Building Airflow Standard” and “Shell Measures” may prevent or arrest the development of mold. Costs associated with this activity will be charged as health and safety costs and will not be included in the average cost per home limitation.

**Severe Indoor Air Quality Problems**

Severe indoor air quality problems, observed at the time of the audit, may disqualify a home from air sealing treatments until the problems are solved. These problems include but are not limited to the following conditions.

- Unsanitary conditions that would put workers at risk or increase risk to the occupants.
- Complaints on the part of occupants that they feel ill when in the home.
- Production of high levels of CO in combustion appliances, including cook stoves.

See “Respiratory health” on page 81. and See “Gas range and oven safety” on page 66.

**Building Airflow Standard (BAS)**

Dwelling units must not be tightened below a level where health, safety, building integrity and indoor air quality may be compromised. A combination of blower door testing and other protocols must be used to provide sufficient assurances consistent with this goal, including issues related to the following.

- Unvented space heater present.
- Indoor air quality and moisture survey.
- BAS
- Chimney safety performance testing.
- Client education.
The auditor and technicians are expected to adjust the BAS to account for moisture problems and other indoor air quality problems or to avoid air-sealing altogether if solving the problems are beyond the scope of the weatherization program. See “Building Airflow Standard (BAS)” on page 211.

**Inadvertent Over-Tightening**

There are instances where technicians can quite easily tighten a house below the BAS. This is often the case with small volume structures, such as manufactured houses. If the home’s BAS is below the calculated limit, greater care must be directed towards client education, and to providing assurances that greater moisture levels or other indoor air quality problems will not develop. Costs associated with installing mechanical spot source ventilation or repairing existing mechanical ventilation are allowable under the health and safety provisions.

**Lead-Based Paint Hazards**

Risk assessment, abatement, hazard control or stabilization of lead-based paint is not an allowable activity under the DOE Weatherization Program. However, work that is needed to prevent generation of dust and residues while performing approved weatherization measures that disturb surfaces that may contain lead based paint is allowable. Costs associated with this activity will be charged as health and safety costs and will not be included in the average cost per home limitation. DOE Lead-Safe Weatherization (LSW) is necessary to prevent the possible exposure and effects of lead to both crew personnel and occupants of the dwelling. Lead safe weatherization as identified are to be performed on dwellings. Refer to the current lead paint protocol established by DOE and EPA.

A copy of the current EPA lead pamphlet will be provided to occupants residing in pre 1978 dwellings, as well as written certification of receipt prior to the start of weatherization work.
All weatherization employees and sub-contractors, whose work duties may result in the disturbance of lead based paint in the course of weatherization, must receive training/certification in lead safe weatherization approved by EPA and DOE. See “Lead-safe weatherization” on page 76.

**Other Health and Safety Issues**

**Building structural integrity** must be assessed at the time of the audit. Certain repairs to the building structure are allowable if they can be completed as a health and safety measure or under the minor repair category, and are necessary for the proper installation of an approved weatherization measure. If adequate repair cannot be accomplished the sub-grantee must take the following steps.

- ✓ Refer the client to other available housing programs to make the necessary repairs.
- ✓ Provide the client reasonable opportunity to make the appropriate repairs to the building.
- ✓ In some instances, it may be necessary to omit a particular weatherization measure due to the condition of a building component. If the building structure is in such disrepair as to make the majority of needed measures ineffective, weatherization may be denied to the client.

Electrical wiring may be susceptible to safety problems resulting from weatherization activities such as insulation retrofits. Agencies are directed to follow specifications outlined in “Electrical safety” on page 170 to avoid electrical and fire hazards.

Replace **Halogen floor lamps** with fluorescent floor lamps. Halogen lamps are now considered to be an extreme fire hazard. See “Halogen Lamps” on page 56.

**Asbestos**, which is friable, is not permitted to be removed, covered, encapsulated, or disturbed during weatherization activities. Dwelling occupants will be given written notice of such discovery, along with the address and telephone number of the regional EPA.
asbestos coordinator. If requested, a reasonable period of time for asbestos removal and clean-up will be given prior to weatherization.

**Other code issues** are the responsibility of the sub-grantee to insure that weatherization related work conforms with applicable codes in jurisdictions where the work is being performed.

**DEFERRAL OF WEATHERIZATION SERVICES**

The decision to defer work in a dwelling or, in extreme cases, provide no weatherization services, is difficult but necessary in some cases. This does not mean that services will never be available, but that work must be postponed until the problems can be resolved. Agencies are expected to pursue all reasonable options on behalf of the client. Know the options for housing repair funds in your region, and help weatherization clients apply for and obtain funding to make repairs that, if left undone, would force you to deny weatherization services.

A deferral is contained in a letter to the client explaining the severe circumstances, leading to the decision to defer weatherization services. The deferral letter must be included in the client file. Reasons for deferral of services include, but are not limited to, the following items.

- The household income may exceed federal poverty guidelines.
- The client or a household member acts in an uncooperative, threatening or abusive manner.
- Criminal behavior is observed in the household.
- Client creates a health, safety, or sanitary risk and refuses to correct the problem.
- Client refuses recommended Priority List health and safety measures.
• Client has known health problems which would preclude insulation or other weatherization materials from being installed.

• Pet containment.

• The building structure or its mechanical systems are in such a state of disrepair that the conditions cannot be resolved cost-effectively.

• The house or site-built/manufactured housing has been condemned for electrical, plumbing, or any other issues, with the exception of heating appliances.

• The house or site-built/manufactured housing has sewage or other sanitary problems that would further endanger the client and installers if weatherization work was performed.

• Moisture problems are so severe that they cannot be resolved under existing health and safety measures and with minor repairs.

• Dangerous conditions exist due to high carbon monoxide levels in combustion appliances that cannot be resolved under existing health and safety measures and with minor repairs.

• The extent of and condition of lead based paint in the house would create further health and safety hazards.

**Final Inspection**

A sub-grantee representative will inspect the completed work and obtain a “completion verification” from the client. This verification will become part of the permanent client file record. Also included in the final inspection report is an assurance that installed measures were explained to the client and that client education was provided. The inspector must verify that the measures, listed on the job report or invoice, were installed on the home and that they were properly installed in accordance with these standards described in this field guide.
Energy-auditing has a logic and a sequence of steps determined by the auditor, the policies of the weatherization agency, and the residence being audited. Before deciding which weatherization measures to install in a particular home you should understand how the home uses energy.

Decisions about which measures to install are determined by visual inspection, auditing experience, practical considerations, and the results of computerized energy-auditing programs like NEAT and MHEA.

Those measures which reduce baseload consumption according to Pennsylvania’s baseload standards are cost-effective energy savers for most homes and don’t require much analysis. These measures may even be installed during the weatherization audit by the auditor. They are covered at the end of this chapter.

The chapters that follow this one are arranged to reflect the auditing process, with measures and testing that are first in sequence and importance being addressed first within each chapter.

Also covered in this chapter is client education. A client can reduce energy consumption, using the suggestions listed here, without any weatherization work. If the auditor is persuasive enough about the benefits of energy-saving habits, weatherization efforts will be measurably more successful than if client education is neglected.

**Title 1 Understanding Energy Usage**

Energy usage can be divided into two categories: baseload and seasonal energy use. Baseload includes water heating, lighting, refrigerator, and the use of other year-round appliances. Seasonal energy use includes heating and cooling.

The challenge of energy auditing is to determine where the loss is and to allocate weatherization resources according to the potential a particular home has for energy loss reduction.

Seasonal energy use is much more variable and difficult to reduce than baseload energy use. In particular, reducing heating costs has become a complex endeavor because of diagnostic procedures and linkages to health and safety.

All-electric homes best demonstrate the distribution of energy usage because all their energy usage is measured in the same units: kilowatt-hours.

**Table Title-1: Low-Income All-Electric Energy Consumption**

<table>
<thead>
<tr>
<th>Electric Energy User</th>
<th>kWh/yr</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space heating</td>
<td>4300</td>
<td>32%</td>
</tr>
<tr>
<td>Water heating</td>
<td>3000</td>
<td>22%</td>
</tr>
<tr>
<td>Cooling</td>
<td>800</td>
<td>6%</td>
</tr>
<tr>
<td>Lighting</td>
<td>1400</td>
<td>10%</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>1300</td>
<td>10%</td>
</tr>
<tr>
<td>Clothes dryer</td>
<td>1100</td>
<td>8%</td>
</tr>
<tr>
<td>Other</td>
<td>1600</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13,500</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Author’s estimates based on information from the Energy Information Administration, Lawrence Berkeley Laboratory.
Each of the energy uses in the pie chart deserves consideration on every home. Insulation levels can be determined easily from observation, but air leakage and heating performance require extensive testing. Water heating is of special interest because of its year-round expense of $15 to $35 per month. Avoid getting too focused on a single loss category.

**Space Heating Energy**

- **R-Values**
- **Air Leakage**
- **Equipment Efficiency**

**Water Heating Energy**

- **Tank R-Value**
- **Hot-Water Usage**
- **Water Temperature**

**Heating energy waste:** Heating energy loss fits into three categories. The challenge to reducing heating costs is finding the largest pockets of energy waste and spending resources on the major problems.

**Water-heating energy loss:** The challenge to reducing water-heating costs is ensuring that all three loss categories have been improved.

**Improvable baseload and seasonal energy uses:** In northern climates heating is the biggest energy user, other energy uses can’t be neglected in a comprehensive weatherization program, which seeks maximum energy savings.
Inspect, measure, and evaluate, then...

**Inspect home exterior for:** Condition of chimney, roof, plumbing vents, windows, doors, siding, foundation, site drainage, crawl space or basement entrance. Note structural and sanitary problems that may disqualify applicant.

**Interview client regarding:** Health and safety problems page 63, comfort problems, problems with heating system page 87, and other relevant observations they may have.

**Test heating system:** Measure CO, worst-case draft test, measure temperature rise, evaluate efficiency page 103, inspect venting system page 109.

**Inspect home interior for:** Health and safety problems; large air leaks page 163; moisture problems page 66; wall, ceiling and floor insulation levels page 172.

**Evaluate baseload measures:** Utilize WAPTAC Refrigerator Replacement Tool to evaluate refrigerator page 50, measure refrigerator temperatures, measure hot-water temperature, count incandescent lights, evaluate shower head water flow.

**Measure air leakage:** Blower door CFM$_{50}$ page 206, building airflow standard page 211, zone pressures page 219, room pressures.

**Evaluate ducts:** Pressure-pan test page 221, duct-induced room pressures page 223, inspect connections page 135; evaluate need for duct insulation page 138.
...strategize, decide, and install.

**Develop a whole-house strategy:** Note room location, chimney location, and obvious problems; ask client about important observations; combine exterior observations with interior observations to formulate a practical strategy for weatherization.

**Communicate with the client:** Include client information in your decision-making; educate clients on actions they can take to save energy; ask clients to undertake these energy-saving actions to reduce energy consumption.

**Improve heating:** Remove causes of excessive CO page 88; repair venting system or reline chimney as appropriate page 109; make efficiency improvements as appropriate.

**Insulate and repair:** Remove moisture sources page 66; repair large air leaks to prevent air infiltration and insulation from filling unwanted areas page 163; insulate ceiling, walls, floor, and foundation as appropriate and cost-effective page 172.

**Reduce baseload energy usage:** Replace refrigerator and/or set frig/freezer temperatures page 50; wrap water heater, if allowed, and set water-heater temperature, install CFLs page 54.

**Seal air leaks:** Seal major air leaks page 163, especially in ceiling, floor, and foundation. Re-test to evaluate building airflow standard page 211.

**Improve ducts:** Seal duct leaks, especially return leaks that cause depressurization page 135; improve duct airflow as appropriate to remove duct-induced room pressures page 139, insulate ducts located in cold basements or crawl spaces page 138.
Title.3 Client Education

Client education is a potent weatherization measure. A well-designed education program engages families in household energy management and assures the success of weatherization measures such as compact fluorescent lamp installation, setback thermostat installation, and furnace filter maintenance. Clients can enhance our weatherization efforts by developing good habits for using energy wisely. The following recommendations are designed to save energy without overwhelming the client.

Title.3.1 Education hand-in-hand with other WAP treatments

The Commonwealth of Pennsylvania introduced education as a part of the Weatherization Assistance Program during the 1988 – 1989 program year. Since that time all Grantees have been directed to develop and implement an education component as an integral part of their individual weatherization programs. This directive was based largely on the 1987 evaluation that showed a 7% energy savings when education was coupled with standard weatherization treatments. Since then, other evaluations in Philadelphia and around the country have verified that energy education can be an extremely cost effective treatment as part of traditional Weatherization Assistance Program. This is totally consistent with current WAP+ design where both the house and the customer are treated holistically. To be most effective, education should be either delivered along with house treatments or come directly after the treatments have been performed.

Like all other components of a weatherization program, education is only effective when properly designed and implemented. The specifics of implementing an education program will certainly vary from agency to agency because of contracts, customers, housing stock, staff and contractors.
The Audit or Estimate “calls out” a set of treatments needed to solve particular problems found in a house. When effective, these treatments will lower utility usage, save the customer money and create a safer, more comfortable environment, however, these treatments may not address the full range of problems reported by the customer and certainly not address customer habits. When performed effectively, customer education can fill this gap and help the customer to maximize all the potential benefits of the Weatherization Assistance Program. The following guidelines have been developed through the experience of WAP Grantees across the country over the last ten years.

**Simple guidelines to help assure education program success**

*Design your program to focus on customer needs, because effective education is need-based.* Reciting a checklist of energy saving options is usually worthless. People don’t care about item number nine. People care first that you care and then if you can offer real solutions to real problems they have spelled out. The content of your education program should be as broad as your customer’s needs but focused on the highest utility usage. Most non-energy issues can be addressed by referrals to other social service programs inside or outside of your agency.

*Get and keep the customer’s attention and focus by making the session interactive with self-help materials and visuals, especially by using house problems as part of a “walk-through”.* Keep the session as simple as possible by focusing on opportunities that will yield the biggest savings or produce the greatest comfort. Dividing the education into discrete tasks helps to keep the customer from being overwhelmed.

*Guarantee good communication: through active conversation (asking questions and really listening to the answers) and hands-on demonstrations.*
**Connect tasks:** to something physical like hands-on demonstrations and, to a lesser degree, paperwork. Educational forms and customer sign-offs can also help assure that education work is consistent across all educators.

### Table Title-2: Qualities of an Effective Educator

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>1.</td>
<td>Knowledgeable</td>
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<tr>
<td>3.</td>
<td>Patient</td>
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<tr>
<td>5.</td>
<td>Understands personalities</td>
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<tr>
<td>7.</td>
<td>Concerned</td>
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<tr>
<td>9.</td>
<td>Listens well</td>
</tr>
<tr>
<td>11.</td>
<td>Persistent</td>
</tr>
<tr>
<td>13.</td>
<td>Firm</td>
</tr>
<tr>
<td>15.</td>
<td>Asks for feedback</td>
</tr>
<tr>
<td>17.</td>
<td>Positive outlook</td>
</tr>
<tr>
<td>19.</td>
<td>Non-confrontational</td>
</tr>
<tr>
<td>2.</td>
<td>Clear</td>
</tr>
<tr>
<td>4.</td>
<td>Demonstrates points</td>
</tr>
<tr>
<td>6.</td>
<td>Helpful</td>
</tr>
<tr>
<td>8.</td>
<td>Active</td>
</tr>
<tr>
<td>10.</td>
<td>Helps audience visualize information</td>
</tr>
<tr>
<td>12.</td>
<td>Presents alternatives</td>
</tr>
<tr>
<td>14.</td>
<td>Sets expectations</td>
</tr>
<tr>
<td>16.</td>
<td>Identifies audience skill level</td>
</tr>
<tr>
<td>18.</td>
<td>Knows own limitations</td>
</tr>
<tr>
<td>20.</td>
<td>Willing to meet someone on their level</td>
</tr>
</tbody>
</table>

### What is Effective Communication

You know your communication has been successful when the person(s) you are talking with have heard what you wanted them to hear and you know this, because they have repeated, drawn or demonstrated your information back to you in a clear manner.
Title 3.2 Reducing heating costs

The auditor should suggest the following practices for reducing heating costs.

✓ Set thermostat back 5 to 10 degrees at night or when no one is home.

✓ Check furnace filters monthly during the heating or cooling season, and change or clean them as necessary.

✓ Open all registers, and don’t obstruct them with furniture or rugs.

✓ Clean grills when they appear dusty.

✓ Check prime and storm windows regularly during cold weather to make sure they are closed.

✓ Oil-fired heating systems should be serviced annually.

Title 3.3 Hydronic heating systems

Additionally, the auditor should explain the following general practices for homeowners who have a hot water or steam boiler system for home heating.

Hot water systems

✓ Periodically bleed the radiators of any excess air. After bleeding air, read the boiler pressure gauge to confirm that the system pressure is still within the specified limits.

✓ Drain the expansion tank every three years or sooner if the radiators seem to have a lot of air or if the safety relief valve keeps blowing out.

✓ Have the boiler cleaned and tuned annually by qualified personnel.

Steam systems (identified by a sight glass that shows boiler water level)
✓ Drain the float chamber and check the low water cutoff weekly. Open the blow-down value and flush the sediment into a bucket until the water runs clear.

✓ After flushing the float chamber, confirm the proper operation of the automatic make-up water valve by checking the sight glass for proper water level.

✓ Have the steam boiler cleaned and tuned annually by qualified personnel.

Title.3.4 Hot-water and laundry savings

The auditor should suggest the following habits for reducing hot-water and laundry energy costs.

Reach for the cold-water tap:
Unless you need hot water, use cold.

✓ If replacing the faucet is necessary, install a model with two separate knobs. Reach for the cold water tap unless you need hot water.

✓ Wash clothes in cold water unless warm or hot water is needed to get dirty clothes clean.

✓ Wash and dry full loads of clothes.

✓ Clean the dryer lint filter after each load.

✓ Use the automatic electronic cycle. Note the dial reading that gets clothes acceptably dry and use that setting consistently.
✓ Ensure that dryer vent damper door closes completely when not in use.
✓ Remove snow from around the dryer vent damper.

**Modern dryer dial:** Somewhere in the middle of the electronic or automatic cycle is the most conservative setting.

✓ Remove lint and outdoor debris from the dryer vent termination.
✓ Dry clothes on a clothesline during nice weather.

**Clothes line:** Drying clothes on a clothesline could save the average family up to $100 per year.

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**Title.3.5 Staying cool during hot weather**

Clients can improve comfort and reduce air-conditioning costs by taking the following advice.

✓ Use circulating fans indoors to improve comfort.
✓ Set your central air conditioner at the highest thermostat setting where it still provides adequate comfort.
✓ Set room air conditioner to run as little as possible while still providing adequate comfort.

✓ Lights and appliances produce considerable heat. Turn them off when not in use.

✓ Close interior doors to reduce floor area cooled by a room air conditioner.

✓ If you don’t have air conditioning, use ventilating fans during the night. In the morning, shut the house up and draw drapes and blinds. If air conditioning is used, keep house closed during the day and night.

Circulating fans: Floor fans, table fans, and ceiling fans create a wind-chill effect indoors, which can improve comfort and reduce cooling costs.

Ventilating fans: Window fans or a whole-house fan remove heat collected during the day. Close the house up tight whenever it is hotter outside than inside.

Title 3.6 Other energy-saving opportunities

Stress the importance of the following general habits.

✓ Turn off lights, TVs, and computers when not in use.

✓ Cook in a microwave oven to save energy over cooking with a standard oven.
Title 4 Assessing Baseload Energy-Saving Opportunities

The energy used by electric or gas appliances in a home that is not used for space conditioning is referred to as baseload energy use. This basic energy load includes lighting, refrigeration, water heating, cooking, laundry appliances and electronics. It does not include heating or air conditioning loads, which is referred to as seasonal energy use. Seasonal energy use is addressed through standard weatherization retrofits.

Baseload energy use does vary throughout the year. Lighting and water heaters are used more during the winter months where refrigerators, well pumps, and dehumidifiers are used more during summer months. However, these variations usually account for only about a 10% increase or decrease in baseload use. Some appliances and plug loads are used seasonally, such as holiday lights, pool pumps, and fans. A weatherization auditor needs to be aware that these items impact the evaluation of the total seasonal use.

It is always a best practice to integrate a Baseload Audit with Energy Education. Total electricity and gas use relates directly to potential electricity and gas savings. Customers who use more electricity and gas tend to save more after weatherization and education services, and are therefore, more cost effective to serve. A Baseload Auditor and Energy Educator must be able to look at a customer’s usage patterns and determine if there are opportunities for savings. Baseload energy use is very connected to energy practices in the home. Auditors have a unique opportunity to communicate the operating costs of existing appliances and practices and the savings potential to the client.

The baseload standards that follow define approved conservation measures and methods that will reduce the baseload energy consumption of weatherization clients.
**Title.5 Refrigerator Replacement**

Refrigerators manufactured before 1990 usually consume over 1000 kilowatt-hours per year. New Energy Star® rated refrigerators use less than 550 kilowatt-hours per year, and many use less than 400 kilowatt-hours per year. Replacement should be considered on a case-by-case basis depending on existing refrigerator energy consumption.

**Title.5.1 Refrigerator Testing Criteria**

The following method may be used to determine eligibility for replacement.

- Use the WAPTAC Refrigerator Analysis Tool, found at www.waptac.org/Refrigerator-Guide/Analysis-Tool.aspx. If the database is used, find the model in the Analysis Tool database and proceed to find the SIR. If the Analysis Tool database does not contain the model, use the Kouba-Cavallo database found at www.kouba-cavallo.com. Enter the annual KWH usage from the database and proceed to find the SIR. If the SIR is 1 or greater, the refrigerator can be replaced.

**Title.5.2 Refrigerator Testing Methodology**

Refer to DCED Directive which contains guidance on the implementation of the Refrigerator Replacement Program.

It is allowable to meter secondary refrigerators or freezers as an educational tool for the client to discontinue or limit use of secondary units. The client should be encouraged to give up two or more units for one larger unit.

**Title.5.3 Waivers, Warranties, Release of Accountability**

If eligible for replacement, a client must sign a release statement. They must agree to trade the old unit for the new unit. The
agreement should include a hold-harmless clause for damages during delivery.

Warranty issues are between the client and the vendor. Leave the vendor information and warranty card with the client to complete and send in.

Measure actual clearance of exterior doors, interior doors and appliance cabinets and compare to appliance specifications to select a model that is deliverable and will fit into client’s available space. Recommend delivery with refrigerator door and base grill removed if needed.

If the client is a renter, obtain a signature from the landlord verifying ownership of the existing refrigerator(s) and acknowledging that any appliance replacement will be the property of the same owner. This may be best obtained during eligibility screening for weatherization.

Replacement units must meet the following size and feature replacement criteria.

- Replacement model is a comparable size.
- Client has been shown a picture of the new unit.
- Compare the size of the existing unit’s fresh food compartment and freezer with those of the new unit so the client is not surprised if there is a difference.
- If a client is willing to trade in more than one unit, they are eligible for the next size larger replacement model.

Upright, chest and freezer only appliances are not eligible for replacement. If, however, a client owns an inefficient 15 cubic foot refrigerator/freezer and a stand-alone freezer only, the agency may replace both units with a new 18-21 cubic foot refrigerator-freezer unit if the energy savings compared to both existing units justify the measure.

Replacement refrigerators should have the following features.

- White in color.
• Freezer on top.
• Auto defrost.
• Standard shelving.
• No ice maker (except when present on old unit).
• No front mounted water or ice dispenser.
• Reversible doors.
• Easy-roll wheels.
• Up-front controls.
• No side by side refrigerator freezer combination units.

*New units will not work if the ambient room temperature is below 60 degrees. Be sure to place the new unit in the house and not the garage or basement if those areas don’t stay over 60 degrees year round.*

**Title.5.4 Disposal of Refrigerators**

The refrigerator vendor must haul away and decommission every old appliance that is replaced. The refrigerator vendor must perform refrigeration recovery according to EPA guidelines. Certifiable proof of decommissioning must be provided by the vendor with billing and included in the Weatherization client file.

**Title.5.5 Refrigerator Maintenance Energy Education Topics**

**Coil Cleaning**

If a refrigerator is not eligible for replacement, show client how to brush and clean condenser coils. Turn unit off to prevent exhaust fan from running while cleaning as the brush could catch in the fan blades.
Coil Cleaning Not Applicable

- Newer refrigerators often have enclosed coils.
- Back coils that are accessible may not need a coil brush to clean.

Temperature Adjustment

Test fresh food and freezer temperatures. Optimal temperatures are 36-40 degrees for fresh food compartment and 0–5 degrees for frozen food compartment. Adjust if set lower than optimal range as this will cause excessive use. Educate the customer about the effect of control settings on energy use.

Educate the customer about the effect that ambient room temperature has on refrigerator usage, including the fact that they can cost twice as much to run if they are set too cool or if they are in a hot room. Refrigerators and freezers run less in a cool location away from any heat source.

The ambient room temperature can affect the testing of a refrigerator or freezer for replacement. There is a mathematical procedure to temperature normalize a metered KWH test that adjusts the test result downward for a test in a warm location and upward for a test in a cool location.
**Title.6 Energy Efficient Lighting**

Fluorescent lighting is among the most cost-effective measures that can be installed, particularly for bulbs that are on for long periods. Energy savings are the greatest for those bulbs that are used the longest periods of time. Auditors should ask the client which bulbs are on most often as those bulbs are the best candidates for fluorescent lighting. Fixtures controlled by dimmers should not be considered unless proper lamps are available to the installer. Incandescent fixtures may be replaced with fluorescent fixtures that accept only fluorescent lamps.

The Auditor/ Educator must carry a variety of CFL’s, including those for dimmable fixtures, 3-way bulbs, candle based bulbs and outdoor bulbs.

**Title.6.1 Compact Fluorescent Lamp (CFL) Replacement**

Interview the client to find which bulbs are used most often. Replace bulbs used two hours or more, including outside bulbs.

Replace incandescent bulbs with comparable light level (lumens) in a compact fluorescent bulb, or more lumens. In other words, the CFL should be at least as bright as the incandescent bulb it is replacing. The fluorescent bulb should be sized at approximately one-third the wattage of the incandescent bulb that is being replaced to provide the equivalent lumen, or light, output. Lumen output for fluorescent bulbs is generally displayed on the packaging.

Exterior incandescent lamps may also be replaced with fluorescent lamps. Exterior fluorescent lamps should be rated for exterior use with a minimum 27 watts with a starting temperature of -12°F and a minimum initial rating of 1,600 lumens. Fluorescent lamps with less than 27 watts may not provide adequate lighting for exterior conditions.
The Auditor/Educator must install CFL’s for the customer. It is not advisable to leave for client to replace. Correct placement of CFL’s is required for maximum energy savings. CFLs and fixtures used for replacement should be ENERGY STAR® rated.

Compact fluorescent lamps: These advanced lamps use about one-third of the electricity of the incandescent lamps they replace.

General Criteria for Purchasing CFL Replacement Bulbs

- **Reliability**- Choose products with a reputation for reliability and safety.
- Highest Efficiency– Choose products with the highest lumens per Watt.
- Versatility- Choose manufacturers or vendors who can provide a variety of products for different applications.
- Cost- Compare costs for comparable bulbs.
- Bulb Life- Choose bulbs with the longest rated life expectancy.
- Availability- Choose bulbs that are readily available.
Title 6.2 Halogen Lamps

Halogen floor lamps operate at 300 to 500 watts and could be a fire hazard. These should be replaced in all instances for health and safety reasons and for the energy efficiency afforded by lower wattage fluorescent floor lamps. Deliver and install replacement lower watt fluorescent floor lamps (45 – 60 watts). A new lamp may be assembled and delivered by a Weatherization crew, contractor or Baseload Auditor.

Disposal of Halogen Floor Lamps

The halogen lamps must be disabled and removed from the property by the agency. The client must sign a release statement surrendering the old halogen floor lamp and giving permission to the agency to disable and remove from the property.

Title 7 Clothes Dryer Improvements

To minimize dryer time replace plastic flex dryer vent with rigid metal vent material not to exceed appliance manufacturer’s specifications. As a fall back measure, vent material must not exceed 25 feet from the dryer location to outlet terminal with a reduction in maximum length of 5 feet for each 90 degree elbow and 2 feet for each 45 degree elbow. All joints must be taped and clamped, or snap locked. No screws are allowed.

If dryer is not vented, and the client uses the dryer, provide venting to outside as health and safety item. An unvented dryer may contribute to moisture problems or dehumidifier use. In some cases, this will mean wiring a new 220V outlet (per NEC code) and/or moving the dryer to properly vent it to the outside.

Inspect the lint trap to insure that it is being cleaned regularly.

Ensuring a dryer has adequate supply air also minimizes drying time. While some units have air inlets on the side or back, many draw air in from under the dryer, which is held off the ground by adjustable legs. If those legs have been broken or removed,
the dryer cannot draw in adequate air and clothes will take a long time to dry. Raise dryer above floor by adjusting legs or other means if air intake is from under the dryer and dryer cycles are lengthened by inadequate air supply.

Energy Education Topics

- Clean lint trap.
- Dry clothes outside when possible.
- Dry full loads of clothes.
- Remove snow from vent outlet.
- Ensure closure of vent damper.

**TITLE.8 WATER HEATING MEASURES**

Unsafe or leaking water heaters may be replaced with a sealed combustion, fossil fuel-fired, or electric water heater.

Hot water measures include the following.

- Combustion Safety Tests for gas, propane or oil water heaters.
- Install pressure and temperature relief valve and discharge pipe in none exists.
- Install an R-11 exterior insulation wrap (unless already well insulated or not recommended).
- Adjust temperature.
- Fix hot water leaks.
- Energy-saving showerheads.
- Install pipe insulation on all exposed hot water pipes and the first six feet of cold water pipes off the top of the water heater.
Title.8.1 Water-heaters

Gas-, propane-, and oil-fired water heaters must be tested as described in Chapter Title "Heating System Specifications". Observe the following general specifications concerning water heaters.

✓ Assure that there are no leaks on domestic hot water distribution piping or faucets as well as anywhere above the hot water storage tank.

✓ A water heater must have a pressure-and-temperature relief valve and a safety discharge pipe. Install a relief valve and discharge pipe if none exists. The discharge pipe should terminate 6 inches above the floor or outside the dwelling as specified by local codes. The discharge pipe should be made of rigid metal pipe or approved high temperature plastic pipe.

✓ Water heaters should be re-insulated to at least R-11 with an external insulation blanket, unless the water-heater label gives specific instructions not to insulate or the water heater is already insulated.

✓ Water heater insulation must not obstruct draft diverter, pressure relief valve, thermostats, hi-limit switch, plumbing pipes, or element/thermostat access plates.

✓ Adjust water temperature between 115° and 120°F with clients’ approval, unless the client has an older automatic dishwasher without its own water-heating booster. In this case the maximum setting is 140°F.
For electric water heater temperature adjustments, make sure that power to the unit is turned off before removing the access panels.

Inspect faucets for hot-water leaks and repair leaks if found.

Electric water–heater safety and efficiency

- Electric water heaters should be serviced by a dedicated electrical circuit.
- Have a qualified person replace damaged wiring and correct loose or improper wiring connections.
- A replacement electric water heater should have an energy factor of at least 0.88 and be equipped with at least three inches of foam insulation.

Gas and oil water-heater replacement

Under the following conditions, a water heater may be replaced:

- Safety
- Leaking
- Cost repair is more than 50% of the cost replacement
Any replacement gas or oil water heater must have an energy factor of at least 0.62 or have a minimum of 2 inches of foam insulation. Replacement water heaters should be wrapped with external insulating blankets for additional savings, unless the manufacturer recommends against installing an external blanket.

In tight homes or homes where the mechanical room is located in living areas, replacement gas or oil water heaters should be either power-vented or sealed-combustion. Sealed-combustion water heaters are preferred in tight homes with the water heater installed in a living space. As an option, electric hot water heaters may be installed.

**Title.8.2 Water heating energy retrofits**

**Gas- and oil-fired water-heater insulation**

✓ Keep insulation at least 2 inches away from the gas valve and the burner access panel. No insulation should be installed below the burner access panel.

✓ Do not insulate the tops of gas- or oil-fired water heaters.
Electric water-heater insulation

- Set both upper and lower thermostat to keep water at 120°F before insulating water heater. Shut off power to the water heater before opening any access panels.
- Insulation may cover the water heater’s top if the insulation will not obstruct the pressure relief valve.
- Access plates should be marked on the insulation facing to locate heating elements and their thermostats.

Pipe insulation

- Insulate all exposed hot water pipes and the first 6 feet of cold-water pipes.
- Cover elbows, unions and other fittings to same thickness as pipe.
- Keep pipe insulation at least 6 inches away from flue pipe.
Interior diameter of pipe insulation sleeve should match exterior diameter of pipe.

**Title.9 Other Baseload Use**

Other causes of high baseload use and seasonal baseload use should be identified and addressed through client education.

- Pump problems, such as sump pump or well pump that runs excessively.
- Secondary refrigerators or freezers.
- Unidentified space heaters.
- Clothes Dryers
- Phantom use; usually identifiable as excessive plug loads.
- Window air conditioning use.
- Dehumidifiers.

If you are unable to determine the cause of high baseload, refer the customer to their utility company. There are service representatives who can visit the house with testing equipment to troubleshoot mystery use. For example, they may test for an electric bleed-to-ground. See “Baseload Auditing Tools and Equipment” on page 247.
CHAPTER TITLE: HEALTH AND SAFETY INFORMATION

This chapter explains some of the most pressing hazards that your clients face in their homes, as well as those you face at work as a weatherization specialist.

The most common home health hazards that are related to weatherization are:

1. Carbon monoxide
2. Moisture problems
3. Lead-based paint dust
4. Gas leaks

When a weatherization agency finds serious safety problems in a customer’s home, the agency should inform the customer in writing about the hazards and make suggestions about how to eliminate them.

The home is second only to the automobile as a dangerous place to be: household accidents kill 24,000 Americans and injure 3,500,000 each year. Children may be at a greater risk because they spend more time at home and are less aware of danger than adults. There are three major causes of non-workplace injuries.

1. Falls
2. Poisoning by solids and liquids
3. Smoke inhalation and burns from fires


TITLE.1 CLIENT HEALTH AND SAFETY

Carbon monoxide, moisture problems, lead-paint dust, and gas leaks are the most important health and safety problems related to weatherization work. When these are detected, inform the
customer verbally and in writing as appropriate. Addressing these problems should be a top priority.

1. Test heating systems and homes for carbon monoxide and solve problems causing CO.

2. Find moisture problems and discuss them with the client. Never make moisture problems worse. See “Gas range and oven safety” on page 66.

3. Practice lead-safe weatherization. See “Lead-safe weatherization” on page 76.

“Client Health and Safety” on page 29 discusses standards for this topic.

**Title 1.1 Carbon monoxide**

Carbon monoxide (CO) is released by combustion appliances, automobiles, and cigarettes as a product of incomplete combustion. CO is the largest cause of injury and death in the U.S. from gas poisoning, resulting in more than 500 deaths per year. Many more people are injured by high concentrations of the gas, or temporarily sickened by lower concentrations of 5-to-50 parts per million (ppm). The symptoms of low-level CO exposure are similar to the flu, and may go unnoticed.

CO blocks the oxygen-carrying capacity of the blood’s hemoglobin, which carries vital oxygen to the tissues. At low concentrations (5-to-50 ppm), CO reduces nerve reaction time and causes mild drowsiness, nausea, and headaches. Higher concentrations (50-to-3000 ppm) lead to severe headaches, vomiting, and even death if the high concentration persists. The effects of CO poisoning are usually
reversible, except for exposure to very high levels, which can cause brain damage.

The EPA’s suggested maximum 8-hour exposure is 9 ppm in room air. Room levels of CO at or above 9 ppm are usually associated with the use of malfunctioning combustion appliances within the living space, although cigarette smoking or automobile exhaust are also common CO sources.

CO is a common problem in low-income housing, affecting 20% or more of residential buildings in some regions. Offending appliances include: unvented gas space heaters, kerosene space heaters, backdrafting vented space heaters, gas ranges, leaky wood stoves, and automobiles idling in attached garages or near the home. Backdrafting furnaces and boilers may also lead to high levels of CO.

The most common CO-testing instruments are electronic sensors with a digital readouts in parts per million (ppm). Follow the manufacturer’s recommendations on zeroing the meter—usually by exposing the meter to clean air. CO testers usually need re-calibration every 6 months or so, using factory-specified procedures.

CO is normally tested near the flame or in the flue of vented appliances. See “Combustion safety and efficiency testing” on page 88. CO is usually caused by one of the following:

- Overfiring
- Backdrafting of combustion gases smothering the flame
- Flame interference by an object (a pan over a gas burner on a range top, for example)
- Inadequate combustion air
- Flame interference by moving air
- Misalignment of the burner
Title.1.2  Gas range and oven safety

Gas ranges and ovens can produce significant quantities of CO in a kitchen. Overfiring, dirt buildup, and foil installed around burners are frequent causes of CO. Oven burners are likely to produce CO even when not obstructed by dirt or foil. Test the range and oven for safety following these steps and take the recommended actions before or during weatherization.

1. Test each stove-top burner separately, using a digital combustion analyzer or CO meter and holding the probe about 8 inches above the flame for 2 minutes. Desired CO level is under 25 parts per million (ppm).

2. Turn on the oven to bake at high temperature. Sample the CO level in exhaust gases at the oven vent and in the ambient air after 10 minutes.

3. If the CO reading is over 100 ppm or if the ambient-air reading rises to 35 ppm or more during the test, take action to reduce these levels. Actions include cleaning the oven, removing aluminum foil, or adjusting the burner’s adjustable gas control.

Advise the client of the following important operating practices.

✓ Never install aluminum foil around a range burner or oven burner.

✓ Never use a range burner or gas oven as a space heater.

✓ Open a window and turn on the kitchen exhaust fan when using the range or oven.

✓ Keep range burners and ovens clean to prevent dirt from interfering with combustion.

✓ Burners should display hard blue flames. Yellow or white flames, wavering flames, or noisy flames should be investigated by a trained gas technician.
Title 1.3 Moisture problems

Moisture causes billions of dollars worth of property damage and high energy bills each year in American homes. Water damages building materials by dissolving glues and mortar, corroding metal, and nurturing pests like mildew, mold and dust mites. These pests, in turn, cause many cases of respiratory distress. Water also reduces the thermal resistance of insulation and other building materials. High humidity also increases air conditioning costs because the air conditioner must remove the moisture from the air to improve comfort.

Relative humidity (rh) is the percentage of the maximum moisture that air at a given temperature can hold. Rh is 100% when the air is saturated with moisture. Add more moisture to saturated air, and water condenses on cool objects. Relative humidity is 50% when the air at a particular temperature is only half saturated with water vapor. Building materials’ moisture content is directly related to the relative humidity of the surrounding air.

High relative humidity in indoor air can cause comfort problems in summer, and condensation problems in both summer
and winter. Experts on cooling say the air should be less than 60% relative humidity for adequate indoor comfort in summer. Experts on winter conditions say that indoor relative humidity in cold climates should be less than 40% to avoid moisture condensation problems.

Moisture enters buildings and moves through them in the forms of liquid water and water vapor. The four categories of water movement are:

- **Liquid flow.** Driven by gravity or air-pressure differences, water flows into a building’s holes and cracks. Roof leaks and plumbing leaks can deposit large amounts of water in a home.

- **Capillary seepage.** Liquid water creates a suction of its own as it moves through tiny spaces within and between building materials. This capillary suction draws water seepage from the ground. Seepage also redistributes water from leaks, spills, and condensation.

- **Air movement.** Air movement carries water vapor into and out of the building and its cavities. Air pressure difference is the driving force for this air movement, and holes in the shell are the leakage paths. If the air reaches saturation (also called the dew point), condensation will occur.

- **Vapor diffusion.** Water vapor will move through solid objects depending on their permeability and the vapor pressure.

Liquid flow is the most serious water threat, because it moves large amounts of water rapidly. Capillary seepage can also move liquid water rapidly into a home through damp soil and a porous foundation.

Water vapor movement by air leakage and diffusion occurs mainly when heating or cooling systems are operating. Winter air leakage tends to carry moist indoor air outdoors—drying the indoor air. Summer air leakage tends to bring moist, hotter air into the home—increasing humidity.
Vapor diffusion is the slowest form of moisture movement and creates fewer problems than the others. However, vapor diffusion can cause condensation inside relatively cool building cavities during both the heating and cooling seasons.

Moisture moves into a building during wet seasons and out during drier seasons. Moisture is a problem when it reaches a level that encourages pests—termites, dust mites, dry rot, and fungus.

Moisture sources: Moisture sources abound in typical homes.

The most common sources of moisture are leaky roofs and damp foundations. Other critical moisture sources include dryers vented to indoors, showers, cooking appliances, hanging wet laundry indoors, drying fire wood supply indoors, and unvented gas appliances like ranges or decorative fireplaces. Climate is also a major contributor to moisture problems. The more rain, extreme temperatures, and humid weather a region has, the more its homes are vulnerable to moisture problems.

Reducing sources of moisture is the first priority for solving moisture problems. Next most important are air and vapor barriers to prevent water-vapor from migrating through building cavities. Relatively airtight homes may need mechanical ventilation to remove accumulating water vapor. Also, see “ Moisture Problems” on page 30.
Symptoms of moisture problems

Condensation on windows, walls, and other surfaces signals high relative humidity and the need to find and reduce moisture sources. During very cold weather or rapid weather changes, condensation may occur. This occasional condensation isn’t a major problem. However, if window condensation is a persistent problem, reduce moisture sources, add insulation, or consider other remedies that lead to warmer interior surfaces. The colder the outdoor temperature, the more likely condensation is to occur. Adding insulation helps eliminate cold areas where water vapor condenses.

Moisture problems arise when the moisture content of building materials reaches a threshold where pests like termites, dust mites, rot, and fungus can thrive. Asthma, bronchitis and other respiratory ailments can be exacerbated by moisture problems because mold, mildew, and dust mites’ protein and feces are potent allergens.

### Table 1: Typical Household Moisture Sources

<table>
<thead>
<tr>
<th>Moisture Source</th>
<th>Potential Amount Pints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground moisture</td>
<td>0–105 per day</td>
</tr>
<tr>
<td>Unvented combustion space heater</td>
<td>0.5–20 per hour</td>
</tr>
<tr>
<td>Seasonal evaporation from materials</td>
<td>6–19 per day</td>
</tr>
<tr>
<td>Dryers venting indoors</td>
<td>4–6 per load</td>
</tr>
<tr>
<td>Dishwashing</td>
<td>1–2 per day</td>
</tr>
<tr>
<td>Cooking (meals for four)</td>
<td>2–4 per day</td>
</tr>
<tr>
<td>Showering</td>
<td>0.5 per shower</td>
</tr>
<tr>
<td>Hanging laundry to dry indoors</td>
<td>8–12 per day</td>
</tr>
<tr>
<td>Drying/seasoning fire wood indoors (one cord)</td>
<td>32 pints</td>
</tr>
</tbody>
</table>
Rot and wood decay indicate advanced moisture damage. Unlike surface mold and mildew, wood decay fungi penetrate, soften, and weaken wood.

Peeling, blistering or cracking paint may indicate that moisture is moving through a wall, damaging the paint and possibly the building materials underneath.

Corrosion, oxidation and rust on metal are unmistakable signs that moisture is at work. Deformed wooden surfaces may appear as damp wood swells and then warps and cracks as it dries.

Concrete and masonry efflorescence is a white, powdery deposit left by water moving through a masonry wall, leaving minerals from mortar or the soil behind as it evaporates.

The Pennsylvania Department of Community and Economic Development uses the following form for assessing the presence of moisture in a home.
Whole House Moisture Assessment

Date: Job Number: Client: Agency Name: Auditor:

Attic access is best described as: Hatch Door None
Attic Ventilation: Yes No Other

Mechanical ventilation: Dryer Range hood Bath fan Other
Are the mechanical vents properly extended: Yes No

Water Moisture Symptoms: Efflorescence Stains Rotted wood Damp floor/walls

Visible mold growth Mildew/odor Rust stains on appliances, etc.

If so, where do they appear in the home?

Pictures Taken for Client File: Yes No

Moisture Contributing Factors: Wet basement Roof leaks Plumbing leaks Other

If other, explain

Comments:

Do any children or elderly reside or frequently visit? Yes No

Does anyone residing in the home have health issues? Yes No

If yes, explain

Repairs recommended prior to weatherization? Yes No

Repair description

Repairs to be completed by: Landlord Homeowner Other

Repair completion verified by:

The above statement regarding moisture history of this dwelling is true and correct to the best of my knowledge.

Recommended repairs must be completed prior to any measures being installed in the home.

Client Signature: X Date:

Auditor Signature: Date:

Reviewed By: Name: Entity:
Mold can be a problem in any home, but especially in those where there is an excessive amount of moisture or humidity present. In addition, if there are several pets, plants, or fish aquariums present, conditions may exist for mold to grow. An assessment of your home included a visual check for mold. This is not a mold inspection and the person making this assessment is not a mold inspector. Testing and identification of specific molds is beyond the scope of this program and we are not liable for mold that was not found during this inspection.

During an energy audit on (date) our personnel identified mold growth in the following room(s) of your home located at:

☐ Living/Bedroom Areas
☐ Bathroom Areas
☐ Laundry Areas
☐ Combustion Areas
☐ Crawlspace Areas
☐ Attic Areas
☐ Basement Areas
☐ Other Location

(Other Location)

Moldy or musty odors are an indicator that there may be hidden mold growth. Moldy or Musty Odors: ☐ Are present ☐ Are not present

The U.S. Department of Energy generally does not allow Weatherization agencies to remedy mold problems, but some actions associated with a cost effective energy saving measure may be taken to reduce moisture problems. We will take the following measures that may help to resolve existing moisture problems:

Sample Weatherization Mold Assessment and Release Form

Weatherization Client: ____________________________ Date: ____________________________
Agency Auditor/Estimator: ____________________________ Date: ____________________________

☐ Moisture/Mold Disclaimer: By signing below, I acknowledge that I have received information concerning moisture and mold conditions in my home prior to any weatherization work being done and I will take steps to reduce excessive moisture. I agree to hold the agency performing weatherization harmless for any future moisture or mold problems that are not associated with the weatherization work.

☐ Deferral Disclaimer: By signing below, I acknowledge that I have been notified there is existing mold in the home prior to any weatherization work being done. I have been advised that the agency performing weatherization cannot cost effectively resolve the identified mold or moisture and that weatherization work must be deferred until the mold or moisture is remedied.

Weatherization Client: ____________________________ Date: ____________________________
Agency Auditor/Estimator: ____________________________ Date: ____________________________
Solutions to moisture problems

Water moves easily as a liquid or vapor from the ground through porous building materials like concrete and wood. Auditors should be aware of how occupant behavior and site conditions affect the moisture problems they see. A high ground-water table can channel moisture into a home faster than anything short of a big roof leak. The most common ground-moisture source is water vapor rising through the soil or liquid water moving up through the soil by capillary action. To prevent this, all crawl spaces should have ground moisture barriers.

A ground moisture barrier is simply a piece of heavy plastic sheeting laid on the ground. Black or clear heavy plastic film works well, but tough cross-linked polyethylene is more durable.

A sump pump is the most effective remedy, when ground water continually seeps into a basement or crawl space and collects there as standing water. Serious ground-water problems may require excavating and installing drain pipe and gravel—to disperse accumulations of groundwater between a home and nearby hillside, for example.

Rainwater flowing from roofs often plays a major role in dampening foundations. In rainy climates, install rain gutters with downspouts that drain roof water away from the foundation.

Preventing moisture problems is the best way to guarantee a building’s durability and its occupant’s respiratory health.
Besides the all-important source-reduction strategies listed above, consider the following additional moisture solutions.

- Installing or improving air barriers and vapor barriers to prevent air leakage and vapor diffusion from transporting moisture into building cavities. See “Sealing bypasses” on page 163.

- Adding insulation to the walls, floor, and ceiling of a home to keep the indoor surfaces warmer and less prone to condensation. During cold weather, well-insulated homes can tolerate higher humidity without condensation than can poorly insulated homes.

- Ventilating the home with drier outdoor air to dilute the more humid indoor air. However, passive ventilation is only effective when the outdoor air is drier than the inside air.

- Removing moisture from indoor air by cooling the air to below its dew point, with refrigerated air conditioning systems (summer) and dehumidifiers (winter).

**Mechanical ventilation**

Ventilation is an important health and safety concern in very airtight homes. These homes have a blower-door-measured air-leakage rate lower than the building airflow standard discussed in “Building Airflow Standard (BAS)” on page 211. Ventilation is also important in homes with pollutant sources: smoking, new furniture, new carpet, etc. Homes with a natural air-change rate lower than the BAS should have mechanical ventilation systems.
The choice comes down to ventilating the whole house or providing spot-ventilation in the kitchen and bathroom where most moisture and odors are generated. Kitchen and bath fans must be vented outdoors, never into crawl spaces or attics.

High quality exhaust fans should have tight-sealing backdraft dampers. Backdraft dampers are located in the fan housing, in the vent duct, or in the termination fitting in the roof or wall.

A low noise level (rated in sones) is important in encouraging occupants to use exhaust fans. The sone rating varies from about 5 sones for the noisiest residential exhaust fans to about 0.5 sones for the quietest fans. The success of spot ventilation and whole-house ventilation depends on how much noise the fan makes. Occupants may not use the fans or may disconnect automatic controls if the fans are too noisy.

Exhaust fans can also provide whole-house ventilation. Make-up air comes from outdoors through the home’s air leaks. Manual switches, dehumidistats, and timers are used to control exhaust fans for whole-house ventilation. Exhaust fans typically run from 2 to 6 hours per day, when providing whole-house ventilation.

**Title.1.4 Lead-safe weatherization**

All dust is dangerous, but lead dust is particularly dangerous because lead is a poison. Children are more vulnerable than adults because of their greater hand-to-mouth behavior. Take all necessary steps, outlined here, to protect customers and their children from lead dust.

Lead-safe weatherization (LSW) is a group of safe practices used by weatherization technicians. LSW practices are little more than very careful dust-prevention and housekeeping precautions. Lead-safe weatherization is required when workers will disturb painted surfaces by cutting, scraping, drilling, or other dust-creating activities.
Technicians should assume the presence of lead based paints in any site built home constructed prior to 1978. Weatherization activities that could disturb lead paint and create lead dust include the following:

- Glazing, weatherstripping, or replacing windows
- Weatherstripping, repairing, or replacing doors
- Drilling holes in the interior or the exterior of the home for installing insulation
- Removing trim or cutting through walls or ceilings to seal air leaks, install ducts, replace windows etc.
- Removing painted siding for installing insulation

When engaging in these activities, follow DOE and EPA lead safe protocols.

Also, see “Lead-Based Paint Hazards” on page 32 and “Unvented Space Heaters” on page 25.

**Title.2 Worker Health and Safety**

Injuries are the fourth leading cause of death in the United States. Long-term exposure to toxic materials contributes to sickness, absenteeism, and death of workers.

The personal health and safety of each employee is vitally important. Preventing injuries on the job is weatherization’s highest priority. Workplace safety standards established by the Occupational Safety and Health Administration (OSHA) as well as other standards established by the construction trade must be observed by weatherization staff and their contractors. Safety always has priority over other factors affecting weatherization operations. The following hazards merit special attention of weatherization agencies and their contractors because of their statistical importance.

1. Driving
2. Falls
3. Back injuries
4. Hazardous materials
5. Electrical and tool hazards
6. Repetitive stress injuries

“Crew or Contractor Health and Safety” on page 28 discusses standards for this topic.

Title.2.1 Commitment to safety

Workers tend to become complacent about their health and safety if its importance is not continually stressed. Weatherization agencies should do the following to encourage safety.

Safety meetings: Safety education and safety meetings are essential parts of a successful safety program.

- Arrange regular health and safety training,
- Conduct regular safety meetings,
- Keep equipment in good condition, and
- Observe all state and federal standards relating to worker health and safety.

Safety requires communication and action. To protect themselves from injury and illness, workers are encouraged to recognize hazards, communicate with co-workers and supervisors, and take action to reduce or eliminate hazards.
Title 2.2 Driving

According to the Bureau of Labor Statistics (BLS), one-third of all occupational fatalities in the United States occur in motor-vehicle accidents. Supervisors and workers should plan and organize their errands and commuting to the job site to minimize vehicular travel. Vehicles should be kept in good repair. Brakes, horns, steering gear, headlights, directional signals, backup lights, and backup signals (when present) should be regularly inspected and repaired if necessary. Workers should always wear seat belts, which should be kept in working order.

Title 2.3 New employees

New employees are more likely to injure themselves on the job compared to experienced workers. Before their first day on the job, new employees should learn about safety basics such as proper lifting, safe ladder usage, and safe operation of the power tools they will use on the job. New employees should be taught how to use safety equipment such as respirators, safety glasses, hearing protection, and gloves. They should also be instructed in proper dress for the job—shorts, sandals, and tank tops are not appropriate.

Supervisors must inform new employees about hazardous materials they may encounter on the job, and teach them to read the
Material Safety Data Sheets (MSDS) required by OSHA for each material.

Alcohol and drugs are prohibited on the job. Encourage staff and coworkers to refrain from smoking and to stay physically fit.

**Title 2.4 Lifting and back injuries**

Back injuries account for one out of every five workplace injuries. Four out of five back injuries are to the lower back; three out of four are the result of improper lifting.

Workers often injure their backs by lifting heavy or awkward loads improperly or without help.

Workers should be instructed in proper lifting techniques—lifting with their legs and keeping a straight back whenever possible. To avoid back injury, employees are encouraged to get help before trying to lift heavy or awkward loads, to stay in good physical condition, and to control their weight through proper diet and exercise. Supervisors should identify workers with limited lifting abilities because of weakness or prior injury and instruct them to avoid heavy lifting.

Other approaches for prevention also include:

1. Redesigning work activities: adapting equipment and minimizing awkward movement on the job site.

2. Administrative controls: strength-testing workers, setting lifting limits, and providing training for all workers on the causes and prevention of back injuries.
Title.2.5 Respiratory health

Common household construction and insulation dust can be full of toxins including lead, asbestos, and chemicals. Drilling, cutting, scraping can stir up toxic dust, which may then be inhaled. Workers are also exposed to dust from the insulation they install. Dust that clings to clothes worn on the job travels home, where it may be inhaled by family members.

Employees are encouraged to wear a respirator when working in a dusty environment. Workers with beards, facial scars, and thick temple bars on eyeglasses must take special care to get a good seal when putting on a respirator. The seal can be tested by putting on the respirator, closing the exhalation valve, and exhaling gently. There should be no leakage of air around the face. Refer to NIOSH for proper type and use of dust mask.

Workers are encouraged to wear coveralls when entering attics or crawl spaces. Coveralls should be disposable or laundered professionally. Workers should be taught how to recognize asbestos insulation that may be installed around older furnaces and boilers. The danger of carrying dust into their own home on their clothing should be stressed. Weatherization contractors and agency staff should be taught how to keep dust out of client’s homes by erecting temporary barriers when they are doing work that may release toxic dust into a client’s home.

Workers should be instructed about the dangers of dust, gases, smoke, vapors, and oxygen-deficient environments. Workers spraying two-part urethane foam should use a respirator canister designed to filter organic vapors and ventilate the area where the foam is being sprayed. For areas, like crawl spaces that are difficult to ventilate, workers should use a supplied-air, positive-pressure respirator.
Title.2.6 Hazardous materials

Workers’ health and safety can be threatened by hazardous materials used on the job. Workers often fail to protect themselves from hazardous materials because they don’t recognize them and understand their health effects. Breathing hazardous materials, absorbing them through the skin, and eye contact with hazardous materials are common ways workers are affected.

OSHA regulations say employers must notify and train employees about hazardous materials used on the job. OSHA requires that a Material Safety Data Sheet (MSDS) for every workplace hazardous material be readily available to employees. Copies of MSDSs are obtained from manufacturers or their distributors.

- Employees should know where MSDSs are kept and how to interpret them.
- Employees should know how to avoid exposure to hazardous materials used on the job and how to clean up chemical spills.
- Employees should be instructed on appropriate protective equipment.
- Employees should wear appropriate protective equipment recommended by the MSDS, while working with any hazardous material.
Title.2.7 Falls

Falls off ladders and stairs cause 13% of workplace injuries according to the National Safety Council. Falls from the same elevation such as slips and trips account for approximately 7% of workplace injuries. Any change in elevation greater than 19 inches must be served by a ladder or stairway.

Broken ladders and ladders that slip because they haven’t been anchored properly are both major causes of on-the-job falls. Worker carelessness and using the wrong ladder for a particular job is also a common cause of falls. Step ladders, for instance, are often used for work that is too far off the ground, forcing workers to stand on the top step or to reach too far.

OSHA regulations say extension ladders should extend at least three feet above the roof or landing they access and shouldn’t have a pitch steeper than four feet of rise for each foot the base is away from the building. Ladders must be blocked or tied firmly in place at the top and bottom when the above rule cannot be observed.

All ladders should be kept in good repair, and should be replaced if they have missing steps or cracked side-rails. Broken ladders should be removed from the equipment storage area. Portable metal ladders should not be used where they may come in contact with electrical conductors.

Ladders must be maintained free of oil, grease, and other slipping hazards. They must not be loaded beyond the maximum intended load for which they were built. Workers should avoid
carrying heavy loads up ladders and operating power tools from ladders.

Scaffolding must be used when working above-ground for sustained time periods. Scaffolds should be built plumb and level. Each leg should be stabilized so that it supports equal weight as other legs. This is especially important on unlevel ground. Planks should be secured to the structure and handrails provided on the sides and ends of the walkway.

Workplaces should be policed regularly to remove slipping and tripping hazards. Workers carrying loads should establish a debris-free walkway.

Title 2.8 Repetitive Stress Injuries

Ergonomics establish good work habits in your office or on the job by the proper posture, hand and arm coordination in the use of tools or office equipment. It has been found that long term injuries can be avoided by stretching just a few minutes a day. As a result new designs are being made in hand and power tools, office equipment as well as every day home equipment uses. Your safety committee should have their ergonomics standard included for your own personal safety.

Title 2.9 Tool safety

The tools used in construction work are dangerous if used improperly. About 90,000 people hurt themselves with hand tools each year. One moment of inattention can cause an injury that can change a worker’s life permanently.
Six basic safety rules can reduce hazards associated with the use of hand and power tools:

1. Keep all tools in good condition with regular maintenance.
2. Use the right tool for the job.
3. Inspect tools for damage before using them.
4. Operate tools according to the manufacturer’s instructions.
5. Provide and use appropriate personal protective equipment.
6. Use ground-fault interrupter extension cords.

**Electrical safety:** Cords should be maintained in good condition. Special ground-fault-interrupter cords or outlets should be used in wet conditions.
PA will elect to use the parameters set forth in its published set of PA Field Standards for Heating System Improvements. Combustion heating systems heat most homes and their operation generates many important topics. Combustion safety and efficiency lead off this chapter because they are the primary tests performed by an auditor. Chimneys, venting, and combustion air are the topics of the middle part of this chapter. Distribution systems, furnaces and boilers, and installation issues follow the sections on combustion.

Gas and oil combustion efficiency and safety are discussed in separate sections. Natural gas and propane systems are basically the same appliances, differing from one another only in operating pressure and the orifice sizes of their burners. The word “gas” used here means either natural gas or propane.

Oil-fired appliances often operate significantly below their maximum fuel-burning efficiency. Adjusting fuel-air mixture, draft, as well as, cleaning the burner and heat exchanger can often boost efficiency noticeably.

Gas furnaces and boilers burn cleanly in comparison to heaters powered by other fuels. The fuel-burning efficiency of gas appliances is difficult to improve, although removing carbon monoxide (CO) from their combustion gases makes them operate more safely.

Forced-air furnaces are the most common type of heating system. Leaky ducts and airflow problems are common problems with furnaces and ducts. This chapter discusses furnaces and ducts in sections: “Furnace operating standards” on page 133, “Duct air-tightness standards” on page 135, and “Improving duct-system airflow” on page 139.
TITLE.1 COMBUSTION SAFETY AND EFFICIENCY TESTING

For both oil and gas, safety-testing is extremely important. Combustion systems with their burners, heat exchangers, and chimneys are often neglected for decades.

**Title.1.1 Gas burner safety and efficiency testing**

These following specifications apply to gas furnaces, boilers, water heaters, and space heaters.

**Atmospheric gas burners:** These burners use the heat of the flame to pull combustion air into the burner. Dilution air, entering at the draft diverter, limits excess air and reduces the likelihood of condensation in the chimney.
Gas-burner inspection and testing

Perform the following inspection procedures and maintenance practices on all gas-fired furnaces, boilers, water heaters, and space heaters. The goal of these measures is to reduce carbon monoxide (CO), stabilize flame, and test safety controls. For information on the effects of CO, see “Carbon monoxide” on page 64.

✓ Look for soot, burned wires, and other evidence of flame roll-out.

✓ Inspect the burners for dust, debris, misalignment, and other flame-interference problems. Clean, vacuum, and adjust as needed.

✓ Inspect the heat exchanger for leaks. See “Inspecting furnace heat exchangers” on page 132.

✓ Assure that all 120-volt wiring connections are enclosed in covered electrical boxes. Furnaces and boilers should have dedicated circuits.

✓ Determine that pilot is burning (if equipped) and that main burner ignition is satisfactory.

✓ Sample the undiluted combustion gases with a calibrated flue-gas analyzer during operation.

✓ Test pilot-safety control for complete gas valve shutoff when pilot is extinguished.

✓ Check the thermostat’s heat-anticipator setting. The thermostat’s heat anticipator setting should match the measured current in the 24-volt control circuit.

✓ Check venting system for proper size and pitch.

✓ Check venting system for obstructions, blockages, or leaks.

✓ Measure chimney draft downstream of the draft diverter.

✓ Drill and non-corrosive plug in PVC vent for sampling hole on Category IV vent.
High temperature silicone and lag bolt in B-vent and concentric flue in manufactured home heating appliances.

Test to ensure that the high-limit control extinguishes flame when the furnace temperature rises within 10% of 200° F.

Measure gas input, and observe flame characteristics if soot, CO, or other combustion problems are present.

Proceed with burner maintenance and adjustment when:

- CO is greater than 100 ppm.
- Visual indicators of soot or flame roll-out exist.
- Burners are visibly dirty.
- Measured draft is low or nonexistent.
- The appliance doesn’t conform to the combustion specifications above.

Gas-burner maintenance includes the following measures.

- Remove causes of CO and soot, such as over-firing, closed primary air intake, and flame impingement.
- Remove dirt, rust, and other debris that may be interfering with the burners.
- Take action to improve draft, if inadequate because of improper venting, obstructed chimney, etc.
- Seal leaks in vent connectors and chimneys.
- Adjust gas input if combustion testing indicates overfiring or underfiring.

### Table Title-1: Combustion Standards for Gas Furnaces

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>70+</th>
<th>80+</th>
<th>90+</th>
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<tbody>
<tr>
<td>Carbon monoxide (CO)</td>
<td>≤ 100 ppm</td>
<td>≤ 100 ppm</td>
<td>≤ 100 ppm</td>
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<tr>
<td>(ppm)</td>
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<tr>
<td>Gross stack temperature (°F)</td>
<td>400°–575°</td>
<td>275°–450°</td>
<td>90°</td>
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<tr>
<td>Temperature rise (°F)</td>
<td>pmib#</td>
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<tr>
<td>Oxygen (%O₂)</td>
<td>4–10%</td>
<td>4–10%</td>
<td>4–10%</td>
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<tr>
<td>Nat gas pressure (IWC)</td>
<td>3.2–3.9</td>
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<td>Prop gas pressure (IWC)</td>
<td>10-12</td>
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<tr>
<td>Draft (IWC)</td>
<td>–5 Pa. or -0.02 IWC</td>
<td>–5 Pa. or -0.02 IWC</td>
<td>25–100 Pa. or +0.1 to +0.4 IWC</td>
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- IWC = inches water column
- as per manufacturer instructions.
- 40–90 degrees temperature rise as a fall back measure.
Measuring BTU input on natural gas appliances

Use the following procedure when it’s necessary to measure the input of a natural gas appliance.

1. Turn off all gas combustion appliances such as water heaters, dryers, cook stoves, and space heaters that are connected to the meter you are timing, except for the appliance you wish to test.

2. Fire the unit being tested, and watch the dials of the gas meter.

3. Carefully count how long it takes for one revolution of 1/2, 1, or 2 cubic-foot dial. Refer to Table Title-2 on page 93 and find that number of seconds in the columns marked “Seconds per Revolution.” Follow that row across to the right to the correct column for the 1/2, 1, or 2 cubic-foot dial. Note that you must multiply the number in the table by 1000. Record the input in thousands of BTUs per hour.

4. If the measured input is higher or lower than input on the name plate by more than 10%, adjust gas pressure up or down within a range of 3.2 to 3.9 IWC.

5. If the measured input is still out of range, replace the existing orifices with orifices sized to give the correct input.
### Table Title-2: Input in thousands of Btu/hr for 1000 Btu/cu. ft. gas

<table>
<thead>
<tr>
<th>Second s per Revolution</th>
<th>Size of Meter Dial</th>
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<tbody>
<tr>
<td>1/2 cu. ft.</td>
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</table>
Title 1.2 Leak-testing gas piping

Natural gas and propane piping systems may leak at their joints and valves. Find gas leaks with an electronic combustible-gas detector, often called a gas sniffer. A gas sniffer will find all significant gas leaks if used carefully. Remember that natural gas rises from a leak and propane falls, so position the sensor accordingly.

✓ Sniff all valves and joints with the gas sniffer.

✓ Accurately locate leaks using a non-corrosive bubbling liquid, designed for finding gas leaks.

✓ All gas leaks should be repaired.

Title 1.3 Oil-burner safety and efficiency

Oil burners require annual maintenance to retain their operational safety and combustion efficiency. Testing for combustion efficiency (steady-state efficiency), draft, carbon monoxide, and smoke should be used to guide and evaluate maintenance. These procedures pertain to oil-fired furnaces, boilers, and water heaters.

Oil-burner inspection and testing

Use visual inspection and combustion testing to evaluate oil burner operation. An oil burner passing visual inspection and giving good test results may need no maintenance. If the test results are outside of weatherization specifications, adjustments may be necessary (i.e. air band adjustments or retention head adjustments).

Follow these steps to achieve a minimum standard for oil-burner safety and efficiency:

✓ Inspect burner and appliance for signs of soot, overheating, fire hazards, or wiring problems.
✓ Verify that all oil-fired heaters are equipped with a barometric draft control, unless they have high-static burners or are manufactured house furnaces.

✓ Assure that all 120-volt wiring connections are enclosed in covered electrical boxes. Each oil furnace or boiler should have a dedicated electrical circuit.

✓ Inspect fuel lines and storage tanks for leaks.

✓ Inspect heat exchanger and combustion chamber for cracks, corrosion, or soot buildup.

✓ Check to see if flame ignition is instantaneous or delayed. Flame ignition should be instantaneous, except for pre-purge units where the burner blower runs for a while before ignition.

✓ Sample undiluted flue gases with a smoke tester, following the smoke-tester instructions. Compare the smoke spot left by the gases on the filter paper with the manufacturer’s smoke-spot scale to determine smoke number. If the smoke number is above 2, clean and tune. Perform a combustion analysis test.

✓ Analyze the flue gas for O₂ or CO₂, temperature, CO, and steady-state efficiency (SSE). Sample undiluted flue gases between the barometric draft control and the appliance.

✓ Measure flue draft between the appliance and barometric draft control and over-fire draft over the fire inside the firebox.

✓ Measure high-limit shut-off temperature and adjust or replace the high-limit control if the shut-off temperature is more than 200° F for furnaces, or 180° F for hot-water boilers without a domestic coil. For hot-water boilers with a domestic coil, set the shut-off temperature as needed for domestic hot-water needs.

✓ Measure transformer voltage, and replace if under specification (check input voltage first).
✓ Assure that barometric draft controls are mounted plumb and level and that the damper swings freely with weight in the correct position (H or V).

✓ Time the CAD cell control or stack control to verify that the burner will shut off, within the time stated on the control body, when the CAD cell is blocked from seeing the flame.

### Table Title-3: Combustion Standards for Oil-Burning Appliances

<table>
<thead>
<tr>
<th>Oil Combustion Performance Indicator</th>
<th>Non-Flame Retention</th>
<th>Flame Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (% O₂)</td>
<td>4–9%</td>
<td>4–7%</td>
</tr>
<tr>
<td>Gross Stack temperature (°F)</td>
<td>325°–600°</td>
<td>300°–500°</td>
</tr>
<tr>
<td>Carbon monoxide (CO) parts per million (ppm)</td>
<td>≤ 100 ppm</td>
<td>≤ 100 ppm</td>
</tr>
<tr>
<td>Steady-state efficiency (SSE) (%)</td>
<td>≥ 75%</td>
<td>≥ 80%</td>
</tr>
<tr>
<td>Smoke number (1–9)</td>
<td>≤ 2</td>
<td>0</td>
</tr>
<tr>
<td>Excess air (%)</td>
<td>≤ 100%</td>
<td>≤ 25%</td>
</tr>
<tr>
<td>Oil pressure pounds per square inch (psi)</td>
<td>≥ 100 psi</td>
<td>≥ 100-150 psi (pmi)*</td>
</tr>
<tr>
<td>Over-fire draft (IWC)</td>
<td>5 Pa. or -.02 IWC</td>
<td>5 Pa. or -.02 IWC</td>
</tr>
<tr>
<td></td>
<td>10–25 Pa. or -0.04–0.1IWC</td>
<td>10–25 Pa. or -0.04–0.1IWC</td>
</tr>
</tbody>
</table>

Gross stack temperature (GST) is as measured in the breech of the heating appliance. Net stack temperature is GST minus combustion air temperature.

* pmi = per manufacturer’s specifications
Oil burner maintenance and adjustment

After evaluating the oil burner’s initial operation, if it falls outside the weatherization specifications, a Clean and Tune (C&T) may be recommended. The following should be considered as minimum tasks to ensure efficiency and safety of the heating appliance.

✓ Verify correct flame-sensor operation.

✓ Units may be derated to the maximum allowed by the manufacturer, or no lower than 350 degrees stack temperature. This applies only to Category I vent.

✓ Replace nozzle.

✓ Clean the burner’s blower wheel.

✓ Replace oil filter(s).

✓ Clean or replace air filter.

Measuring oil-burner performance: To measure oil-burning performance indicators, a manometer, flue-gas analyzer, smoke tester, and pressure gauge are required.
**Oil burner:** Performance and efficiency will deteriorate over time if neglected. Annual maintenance is recommended.

- Remove soot, ash, carbon, and sulphur accumulations from combustion chamber.
- Remove soot, ash, and sulphur from heat exchanger surfaces.
- Clean dust, dirt, and oily deposits from the burner assembly.
- Set oil pump to correct pressure (PMI).
- Adjust air shutter and retention head clearances (PMI) to achieve oxygen and smoke values, specified in *Table Title-3, “Combustion Standards for Oil-Burning Appliances,”* on page 96.
- Adjust barometric damper for flue draft of -5–10 pascals or -0.02-to-0.04 IWC (before barometric damper).
- Adjust gap between electrodes to manufacturer’s specifications.
- Repair the combustion chamber, or replace it if necessary.

After these maintenance procedures, the technician performs the diagnostic tests described previously to evaluate improvement made by the maintenance procedures and assure peak efficiency.
Burner replacement with flame-retention burner

A flame-retention burner is a newer type of oil burner that gives a higher combustion efficiency by swirling the mist or oil and air to produce better mixing. Modern flame-retention burners improve combustion efficiency and have steady-state efficiency (SSE) of 80% or slightly more. Replacing an old-style burner with a flame-retention model may be cost-effective if 75% SSE cannot be achieved. Flame-retention-burner motors run at 3450 rpm and older oil burners run at 1725 rpm motor speed. Looking for the nameplate motor or pump speed can help you discriminate between the flame-retention burners and non-retention conventional burners.

If a high-mass furnace or boiler has a sound heat exchanger but the oil burner is inefficient or unserviceable, the burner may be replaced by a newer flame-retention burner. The higher heat from a flame-retention burner may crack the heat exchanger of a low-mass furnace or boiler that had been previously fired by a lower temperature non-retention burner. The new burner must be tested for efficient and safe operation as described previously.

- Units may only be derated by a maximum of 15% from the manufacturer’s specifications, or no lower than 350 degrees stack temperature.
- Install a new combustion chamber, choosing one that fits the size and shape of the burner flame. Or, change nozzles on the new burner to produce a flame that fits an existing combustion chamber that is still in good condition. Either way, the flame must fill the combustion chamber without impingement.
The main purpose of measuring draft is to insure that the combustion gases are being vented from a dwelling. Draft is measured in inches of water column (IWC) or Pascals. House pressure affects draft and must be measured and controlled.

Technicians create worst-case conditions for naturally draft- ing appliances in order to insure that appliances will draft even in worst-case conditions of house depressurization. Depressurization is among the leading cause of backdrafting and flame roll-out. Testing for adequate draft of all combustion appliances is required before final inspection. Category I Venting must be negative pressure in the flue. Category IV will be positive pressure in flue.

<table>
<thead>
<tr>
<th>Pascals</th>
<th>Inches of water column (IWC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0.01 0.02 0.03 0.04</td>
<td></td>
</tr>
</tbody>
</table>

Design chimney draft (80+)
Title.2.1 Draft characteristics in combustion appliances

There are several different classifications of combustion appliances based on the type of draft they employ to exhaust their flue gases. Most existing appliances exhaust their gases into an atmospheric chimney. An atmospheric chimney produces negative draft—a slight vacuum. The strength of this draft is determined by the chimney’s height, its cross-sectional area, and the temperature difference between the flue gases and outdoor air. Atmospheric draft should always be negative.

Most existing gas and oil appliances are designed to operate with at least negative 0.02 inches of water column (IWC) or –5 pascals chimney draft. Tall chimneys located indoors can produce strong drafts and short chimneys or outdoor chimneys typically produce weaker drafts. Wind and house pressures also affect draft.

Atmospheric combustion appliances exhaust combustion gases solely by their buoyancy. Fan-assisted appliances have the help of a small fan near the exhaust of their heat exchanger that regulates airflow through the heat exchanger.
Power burners have fans at the intake of the combustion chamber to mix combustion air with fuel and inject the mixture into the combustion chamber. The standard power oil burner is the most common type of power burner. Most appliances with draft-assisting fans and power burners vent into atmospheric chimneys.

Positive-draft appliances, which are either condensing or non-condensing, vent either horizontally or vertically and require airtight chimneys. Most positive-draft appliances are condensing furnaces and boilers. Most non-condensing positive-draft appliances are boilers, although some furnaces and newer water heaters are also designed to vent through positive-draft, sidewall vents. These appliances have draft in the range of +0.05 to +0.35 IWC or 12 to 85 pascals and are much less influenced by indoor and outdoor pressures.

Power venters with sidewall vents are a good alternative, when a vertical chimney is inadequate or non-existent. The power venter is located near the end of the vent and creates a negative draft. See “Manufactured House furnace venting” on page 123.

Title.2.2 Worst-case combustion appliance zone tests

This test uses the home’s exhaust fans, air handler, and chimneys to create worst-case depressurization in the combustion-appliance zone (CAZ). A combustion appliance zone (CAZ) is an area containing one or more combustion appliances. During this worst-case testing, you measure chimney draft. Draft is the pressure difference between the chimney and combustion zone.
The reason for this test is that worst-case conditions do occur, and chimneys should vent their combustion gases even under these extreme conditions. The three main influences on worst-case draft scenario are depressurization, chimney characteristics, and tightness of the home. This worst-case draft test will discover whether or not the venting system will exhaust the combustion gases when the combustion-zone pressure is as negative as you can make it. A sensitive manometer is usually used for accurate and reliable readings of chimney draft.

**Title.2.3 CAZ Combustion Safety Test**

1. Record outdoor ambient air temperature
2. Zero gas leak detector and Carbon Monoxide Meter to outdoor ambient air conditions
3. Check all gas and or fuel lines to all appliances for leaks and make required repairs before performing test.
4. Using a manometer measure the base pressure of the CAZ with reference to outside, start with all exterior doors, windows and fireplace damper(s) closed or sealed, if possible. Set all combustion appliances to the pilot setting or turn off the service disconnect, including: Boiler, furnace, space heaters, water heater, and/or any device that will exhaust air from the structure. With the structure in this configuration, measure and record the base pressure of the combustion appliance zone With Reference To (WRT) outside.
5. Establish the worst case CAZ by turning on the dryer, all exhaust fans and exhaust devices, and the air handler fan, if present. If a fireplace is present and cannot be sealed off, turn on blower door and exhaust 300CFM. Check the CAZ pressure before and after closing each interior door, one door at a time. If the CAZ pressure is more negative with the door open, leave the door open. If the CAZ pressure is more negative with the door
closed, leave it closed. Always measure the pressure With Reference To (WRT) the CAZ, so make sure the hose is long enough (the DG-700 manometer comes with 30' of hose). Close any interior doors that make the CAZ pressure more negative. Turn on the air handler fan, if present and leave on if the pressure in the CAZ becomes more negative, and then recheck the door positions. Measure the net change in pressure from the CAZ to outside, corrected for the base pressure. Record the “worst case depressurization”.

6. Compare to chart (CAZ depressurization Limits). If CAZ does not meet CAZ depressurization limits, recommend outside air to CAZ. Locate what is depressurizing the CAZ (i.e. whole house fan). Recommend that the device not be used until the depressurization problem is corrected.

7. Before and during the Spillage, draft and Carbon Monoxide tests, monitor the ambient CO in the breathing zone. Abort the test if the ambient CO level exceeds 35ppm. Turn off the appliance, ventilate the space and evacuate the structure. The structure may be reentered once ambient CO levels have gone below 35ppm. The appliance must be repaired and the problem corrected prior to completing the combustion safety diagnostics.
8. While under worst case CAZ start the heating appliance, beginning with the smallest BTU rated appliance first and using a smoke bottle, test for Spillage at the draft diverter, the appliance should not spill more than 60 seconds. If spillage ends within 60 seconds test draft.

9. Follow the Protocol for Draft Testing* (Check draft after the draft diverter for gas, and before the barometric draft damper on oil, compare to Table 3-4: "Minimum Worst-Case Draft" on outdoor temperature).

10. Once the appliance has reached Steady State measure the CO level at the flue, the CO level should never exceed 100ppm or the Manufacturers specifications. If CO exceeds these levels a clean and tune is required.
11. Repeat steps 8, 9 and 10 for each heating appliance located in the combustion appliance zone

12. Perform steps 8, 9 and 10 with all appliances operating at the same time

13. If Spillage, draft and CO PASS under Worst case skip to line 15

14. If Spillage, and or draft FAIL under worst case turn off the appliance, exhaust fans and exhaust devices, open interior doors and allow the vent to cool before re-testing. Test for CO, spillage and draft under “natural conditions”. Measure the worst case depressurization taken in step 5. Repeat for each appliance, and then with all appliances operating, allowing the vent to cool between each test

15. Make recommendations or complete work order for repairs based on test results.

Note: Documentation of a chimney safety performance test must be included in the client file.
Title 2.4 * Protocol for Draft Testing

Measure flue pressure at steady-state operating conditions of all heating and hot water combustion appliances.

Gas appliances

1. Atmospheric or Natural Draft (70%): Draft testing shall be done in the center of the longest, straightest, accessible section of the vent connector after the draft diverter. Holes made for the purpose of measuring draft shall be drilled using 5/16th bit. Once test is complete, seal hole with High Temperature RTV silicone caulk, cover with aluminum tape or metal plug.

2. Induced Draft (80%) furnaces: Draft testing shall be done downstream of the inducer motor. The preferred location for CO testing is the same hole used for draft testing. Holes made for Draft and CO testing shall be drilled using a 5/16th bit. Once test is complete, seal hole with High Temperature RTV silicone caulk, cover with aluminum tape or metal plug. If using B-vent completely seal the inner liner with High Temperature RTV silicone caulk and a 3/8 inch tap bolt made of stainless steel or seal interior hole with RTV silicone and cover exterior hole with aluminum tape.

3. Sealed Combustion or Power Vented appliances or water heaters (90% +): No draft measurement required, unless venting issues are suspected.

Oil appliances

Natural draft oil fired hot air, hot water, steam boilers and oil fired water heaters, measure draft at or in the breech or at the stack pipe (properly, just above the flue vent connector) measured just a few inches above the boiler or furnace top, and before the barometric damper itself and no closer than 2 pipe sizes in diameter from any elbow. Drill a 5/16” hole in the flue
gas exhaust pipe and seal hole with High Temperature RTV silicone caulk, cover with aluminum tape or metal plug.

**Title.2.5 Improving inadequate draft**

If measured draft is below minimum draft pressures, investigate the reason for the weak draft. Open a window or door to observe whether the addition of combustion air will improve draft. If this added air strengthens draft, the problem usually is depressurization. If opening a window has no effect, inspect the chimney. The chimney could be blocked or excessively leaky. Consider implementing the following improvements in order to solve draft problems.

**Chimney improvements**

- Repair or remove chimney obstructions, disconnections, or leaks, which can weaken draft.
- Measure the size of the vent connector and chimney and compare to vent-sizing information listed in Section 504 of the *International Fuel Gas Code*. A vent connector or chimney liner that is either too large or too small can result in poor draft.
- If wind is causing erratic draft, consider a wind-dampening chimney cap.
- If the masonry chimney is deteriorated, consider installing a new chimney liner. See “Metal liners for masonry chimneys” on page 115.

**Duct improvements**

- Repair and seal return-duct leaks near furnace.
- Isolate furnace from return registers by air-sealing.
- Improve balance between supply and return air by installing new return ducts, transfer grills, or jumper ducts. See “Improving duct-system airflow” on page 139.
Reducing depressurization from exhaust devices

✓ Isolate furnace from exhaust fans and clothes dryers by air-sealing between the combustion zone and zones containing these depressurizing forces.

✓ Reduce capacity of large exhaust fans.

Combustion and make-up air

✓ Provide make-up air for dryers and exhaust fans.

✓ Provide combustion-air inlet to combustion zone. See “Combustion air” on page 126.

TITLE.3 VENTING COMBUSTION GASES

Proper venting is essential to the operation, efficiency, safety and durability of combustion heaters. Reference the most stringent code. The National Fire Protection Association (NFPA) and the International Code Council (ICC) are the authoritative information sources on material-choice, sizing, and clearances for chimneys and vent connectors, as well as for combustion air. The information in this venting section is based on the following NFPA and ICC documents.

- The International Mechanical Code (IMC) 2009 edition
- The International Residential Code (IRC) 2009 edition

Title.3.1 General venting requirements

Combustion gases are vented through vertical chimneys or
other types of approved horizontal or vertical vent piping. Identifying the type of existing venting material, verifying the correct size of vent piping, and making sure the venting conforms to the applicable codes are important tasks in inspecting and repairing venting systems. Too large a vent often leads to condensation and corrosion. Too small a vent can result in spillage. The wrong vent materials can corrode or deteriorate from heat.

### Table Title-5: Venting and Combustion Air Standards

<table>
<thead>
<tr>
<th>Topic</th>
<th>Standard and Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimneys, Vents, and Sizing</td>
<td>NFPA 54 2006, Chapter 13</td>
</tr>
<tr>
<td></td>
<td>IRC 2009, Chapter 24</td>
</tr>
<tr>
<td></td>
<td>IMC 2009, Chapter 8</td>
</tr>
<tr>
<td>Clearances</td>
<td>NFPA 54 2006, Section 12.8.4.4</td>
</tr>
<tr>
<td></td>
<td>IMC 2009, Section 801.18.4</td>
</tr>
<tr>
<td></td>
<td>NFPA 31 2006, Chapter 10</td>
</tr>
<tr>
<td></td>
<td>NFPA 211 2006, Many sections</td>
</tr>
<tr>
<td>Combustion Air</td>
<td>NFPA 54 2006, Section 9.3</td>
</tr>
<tr>
<td></td>
<td>IMC 2009, Chapter 7</td>
</tr>
<tr>
<td></td>
<td>IRC 2009, Chapter 24</td>
</tr>
<tr>
<td></td>
<td>NFPA 31 2006, Section 1-9;</td>
</tr>
<tr>
<td></td>
<td>NFPA 211 2006, Section 8.5 and 9.3</td>
</tr>
</tbody>
</table>

### Title.3.2 Vent connectors

A vent connector connects the appliance’s venting outlet or appliance breach with the chimney’s inlet or chimney breach. Approved vent connectors for gas- and oil-fired units are made from the following materials.

1. Type-B vent, consisting of a galvanized-steel outer pipe and aluminum inner pipe ($\geq 0.027$ inch thick)

2. Type-L vent connector with a stainless-steel inner pipe and either galvanized or black-steel outer pipe.

3. Galvanized-steel pipe ($\geq 0.018$ inch thick)

4. Aluminum pipe (0.027 inch thick)
5. Stainless-steel pipe (≥ 0.012 inch thick)

6. Various manufactured vent connectors

Double-wall vent connectors are the best option, especially for appliances with horizontal sections of vent connector. A double-wall vent connector helps maintain flue-gas temperature and prevent condensation. Gas appliances with draft hoods, installed in attics or crawl spaces must use a Type-B vent connector. Type-L vent pipe is commonly used for vent connectors for oil and solid fuels but can also be used for gas.

Observe the following general specifications, concerning vent connectors.

- A vent connector is almost always the same size as the vent collar on the appliance it vents.
- Vent-pipe sections should be fastened together with 3 screws or rivets.
- The vent connector should be sealed where it enters the chimney.
- Vent connectors should be free of rust, corrosion and holes.
- The chimney combining two vent connectors should have a cross-sectional area equal to the area of the larger vent connector plus half the area of the smaller vent connector. The common vent should be no larger than 7 times the area of the smallest vent. For specific vent sizes, see NFPA codes themselves listed in “Venting and Combustion Air Standards” on page 110.

Table Title-6: Areas of Round Vents

<table>
<thead>
<tr>
<th>Vent diameter</th>
<th>4&quot;</th>
<th>5&quot;</th>
<th>6&quot;</th>
<th>7&quot;</th>
<th>8&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vent area (square inches)</td>
<td>12.6</td>
<td>19.6</td>
<td>28.3</td>
<td>38.5</td>
<td>50.2</td>
</tr>
</tbody>
</table>
• The horizontal length of vent connectors shouldn’t be more than 75% of the chimney’s vertical height or have more than 18 inches horizontal run per inch of vent diameter.

• Vent connectors must have upward slope to their connection with the chimney. A slope of 1/4 inch of rise per foot of horizontal run along their entire length is recommended to prevent condensation from pooling and rusting the vent.

Two vent connectors joining chimney: The water heater’s vent connector enters the chimney above the furnace because the water heater has a smaller input.

| Table Title-7: Vent Connector Diam (in.) and Max Horiz Length (ft.) |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 3"   | 4"    | 5"    | 6"    | 7"    | 8"    | 9"    | 10"   | 12"   | 14"   |
| 4.5'  | 6'    | 7.5'  | 9'    | 10.5' | 12'   | 13.5' | 15'   | 18'   | 21'   |

From International Fuel Gas Code 2000

• When two vent connectors connect to a single chimney, the vent connector servicing the smaller appliance should enter the chimney above the vent for the larger appliance.

• Maintain minimum clearances from combustibles as specified by the connector’s manufacturer.
Title 3.3 Chimneys

There are two common types of vertical chimneys for venting combustion fuels that satisfy NFPA and ICC codes. First there are masonry chimneys lined with fire-clay tile, and second there are manufactured metal chimneys, including all-fuel metal chimneys and Type-B vent chimneys for gas appliances.

Masonry chimneys

Observe the following general specifications for inspecting, repairing, and retrofitting masonry chimneys.

- Masonry chimneys should be supported by their own masonry foundation.
- Existing masonry chimneys should be lined with a fireclay flue liner. There should be a 1/2-inch to 1-inch air gap between the clay liner and the chimney's masonry to insulate the liner. The liner shouldn’t be bonded structurally to the outer masonry because it needs to expand and contract independently of the chimney’s masonry structure. The clay liner can be sealed to the chimney cap with a flexible high-temperature sealant.
- The chimney’s penetrations through floors and ceilings should be sealed with metal as a firestop and air barrier.
- Deteriorated or unlined masonry chimneys may be rebuilt as specified above or relined as part of a heating-system...
replacement or a venting-safety upgrade. As an alternative, the vertical chimney may be replaced by a sidewall vent, equipped with a power venter mounted on the exterior wall.

- Maintain minimum clearances from combustibles as specified by the chimney’s equipment manufacturer.

- Masonry chimneys should have a cleanout 12 inches or more below the lowest inlet. Mortar and brick dust should be cleaned out of the bottom of the chimney through the clean-out door, so that this debris won’t eventually interfere with venting.

** Manufactured chimneys**

Manufactured metal chimneys have engineered parts that fit together in a prescribed way. Metal chimneys have all manufactured components from the vent connector to the termination fitting on the roof. Parts include: metal pipe, weight-supporting hardware, insulation shields, roof jacks, and chimney caps. One manufacturer’s chimney may not be compatible with another’s connecting fittings.

All-fuel metal chimneys come in two types: insulated double wall metal pipe and triple-wall metal pipe. Install them strictly observing the manufacturer’s specifications.

Type-B vent pipe is permitted as a chimney for Category I gas appliances, but adhere to manufacturer’s instructions. Some older manufactured gas chimneys were made of metal-reinforced asbestos cement.
Chimney termination

Masonry chimneys and all-fuel metal chimneys should terminate at least three feet above the roof penetration and two feet above any obstacle within ten feet of the chimney outlet. Chimneys should have a cap to prevent rain and strong downdrafts from entering.

B-vent chimneys can terminate as close as one foot above flat roofs and pitched roofs up to a 6/12 roof pitch. As the pitch increases, the minimum termination height rises as shown in the table.

Table Title-8: Roof Slope and B-Vent Chimney Height Above Roof

<table>
<thead>
<tr>
<th>Flat-6/12</th>
<th>6/12-7/12</th>
<th>7/12-8/12</th>
<th>8/12-9/12</th>
<th>9/12-10/12</th>
<th>10/12-11/12</th>
<th>11/12-12/12</th>
<th>12/12-13/12</th>
<th>13/12-14/12</th>
<th>14/12-15/12</th>
<th>15/12-16/12</th>
<th>16/12-17/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1'</td>
<td>1'</td>
<td>1'</td>
<td>1'</td>
<td>1'</td>
<td>2'</td>
<td>2'</td>
<td>2'</td>
<td>2'</td>
<td>3'</td>
<td>3'</td>
<td>4'</td>
</tr>
<tr>
<td>3'</td>
<td>3'</td>
<td>3'</td>
<td>3'</td>
<td>3'</td>
<td>4'</td>
<td>5'</td>
<td>6'</td>
<td>7'</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From International Fuel Gas Code 2000

Metal liners for masonry chimneys

Unlined masonry chimneys or chimneys with deteriorated liners should be relined as part of heating system replacement. For gas applications use either Type-B vent, or a flexible stainless-steel or aluminum liner. For oil applications use Type-L or flexible stainless liner. See also “Manufactured House furnace venting” on page 123.
Flexible liners require careful installation to avoid a low spot at the bottom, where the liner turns a right angle to pass through the wall of the chimney breach. Follow the manufacturer’s instructions, which usually prescribe stretching the liner and fastening it securely at both ends, to prevent it from sagging and thereby creating such a low spot.

To reduce condensation, flexible liners should be insulated—especially when installed in exterior chimneys. Insulate all rigid and flexible metal chimney liners with Pearlite or suitable material. Follow manufacturer’s installation instructions.

Sizing flexible chimney liners correctly is very important. Oversizing is common and can lead to condensation and corrosion. The manufacturers of the liners include vent-sizing tables in their instructions. Liners should bear the label of a testing lab like Underwriters Laboratories (UL).
Title.3.4 Special venting considerations for gas

The American Gas Association (AGA) has devised a classification system for venting systems serving natural gas and propane appliances. This classification system assigns Roman numerals to four categories of venting based on whether there is positive or negative pressure in the vent and whether condensation is likely to occur in the vent.

A great majority of appliances found in homes and multifamily buildings are Category I, which have negative pressure in vertical chimneys with no condensation expected in the vent connector or chimney. Condensing furnaces are usually Category IV with positive pressure in their vent and condensation occurring in both the appliance and vent.

### Venting fan-assisted furnaces and boilers

Newer gas-fired fan-assisted heating appliances control flue-gas flow and excess air better than atmospheric heaters, resulting in higher efficiency. These are non-condensing Category I heating appliances in the 80%-plus Annual Fuel Utilization Efficiency (AFUE) range. Because these units eliminate dilution air and have slightly cooler flue gases, chimneys should be carefully inspected to ensure that they are suitable for a possibly more corrosive flue-gas flow. The chimney should be relined when any of the following three conditions are present.
1. When the existing masonry chimney is unlined.

2. When the old clay or metal chimney liner is deteriorated.

3. When the new heater has a smaller input than the old one. In this case the new chimney should be sized to the new furnace or boiler and the existing water heater.

For gas-fired 80+ AFUE furnaces, a chimney liner should consist of:

- Type-B vent
- A rigid or flexible stainless steel or aluminum liner
- A poured masonry liner

**Power venters for sidewall venting**

Power venters are installed just inside or outside an exterior wall and are used for sidewall venting. Power venters create a stable negative draft.

Many power venters allow precise control of draft through air controls on the their fans. Barometric draft controls can also provide good draft control when installed either on the common vent for two-appliances or on the vent connector for each appliance.
This more precise draft control, provided by the power venter and/or barometric damper, minimizes excess combustion and dilution air. Flue gas temperatures for power venters can be cooler than temperatures needed to power vertical atmospheric chimneys. Less excess air and cooler flue gases can improve combustion efficiency in many cases. However, the power venter must be installed by a technician familiar with adjusting the draft to each appliance.

A single power venter can vent both a furnace or boiler and also a water heater. Types B or L vent are good choices for horizontal vent piping. Use Type B for gas only.

Power venters should be considered as a venting option when:

- Wind, internal house pressures, or nearby buildings have created a stubborn drafting problem that other options can’t solve.
- An existing horizontally vented appliance has weak draft and/or condensation problems.
- The cost of lining an unlined or deteriorated chimney exceeds the cost of installing a power venter with its horizontal vent.
- A floor furnace or other appliance with a long horizontal vent connector has backdrafting problems.
Pressurized sidewall vents

Sometimes, the manufacturer gives the installer a venting choice of whether to install a fan-assisted furnace or boiler into a vertical chimney (Category I) or as a positive-draft appliance (Category III), vented through a sidewall vent. Sidewall-vented fan-assisted furnaces and boilers may vent through B-vent or stainless-steel single-wall vent pipe. Pressurized sidewall vents must be airtight at the operating pressure. B-vent must be sealed with high-temperature silicone caulking or other approved means to air-seal its joints.

Some high-temperature positive-draft plastic vent pipe, used in horizontal installations, was recalled by manufacturers because of deterioration from heat and condensation. Deteriorated high-temperature plastic vent must be replaced by airtight stainless-steel vent piping or B-vent.

Existing fan-assisted appliances may have problems with weak draft and condensation when vented horizontally. Horizontally vented, fan-assisted furnaces and boilers may require a power venter to create adequate draft.

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Table Title-9: Characteristics of Gas Furnaces and Boilers

<table>
<thead>
<tr>
<th>AFUE</th>
<th>Operating characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>70+</td>
<td>Category I, draft diverter, no draft fan, standing pilot, non-condensing, indoor combustion and dilution air</td>
</tr>
<tr>
<td>80+</td>
<td>Category I, no draft diverter, draft fan, electronic ignition, indoor combustion air</td>
</tr>
<tr>
<td>90+</td>
<td>Category IV, no draft diverter, draft fan, low-temperature plastic venting, positive draft, electronic ignition, condensing heat exchanger, outdoor combustion air is to be provided</td>
</tr>
</tbody>
</table>
Fan-assisted gas heaters with vertical chimneys: These 80% AFUE central heaters are almost always vented into atmospheric chimneys, which may need to be relined.

Fan assisted heaters with sidewall vents: Sometimes these appliances are vented through a side wall through airtight plastic or stainless-steel vent pipe.

Condensing furnace venting: The two common types of termination for plastic condensing vents are separate pipes or a concentric fitting. Vents going through the roof are preferred for their being more resistant to tampering and damage.
Condensing-furnace venting

Condensing furnaces with 90+ AFUE are vented horizontally or vertically through non-cellular PVC Schedule 40 pipe. The vent is pressurized, making it Category IV. Vent piping should be sloped back toward the appliance, so the condensate can be drained and treated if necessary.

Combustion air is supplied from outdoors through a sealed plastic pipe or from indoors. Outdoor combustion air is required, and most condensing furnaces are equipped for outdoor combustion air through a dedicated inlet pipe. This combined combustion-air and venting system is referred to as direct-vent or sealed-combustion.
Manufactured houses require furnaces designed and approved for use in manufactured houses. Manufactured House furnaces are direct-vented, sealed-combustion units that require an outdoor source of combustion air. Manufactured House furnaces may be atmospheric (no draft fan) or fan-assisted. The fan may draw combustion air from a concentric space created by the double-wall chimney or from a duct connected to the ventilated crawl space. Manufactured House furnaces often have a manufactured chimney that includes a passageway for admitting outdoor combustion air supply.

When replacing standard manufactured house manufactured house furnaces, note the differences between the old furnace and new in the way each supplies itself with combustion air, and follow manufacturer’s installation instructions exactly. The chimney assembly must often be replaced when the furnace is replaced. The roof jack may need to be replaced, and the hole for the chimney moved. It is essential that the chimney be vertical and that the chimney cap not be tipped. Many callbacks are caused by chimney and chimney-cap alignment. See “Heating appliance replacement” on page 230.

Manufacturers now produce condensing furnaces that are HUD-approved for use in manufactured housing. These posi-
tive-draft furnaces may eliminate venting and combustion-air problems, common to manufactured house furnaces, because of their robust positive draft and negatively pressurized combustion-air vent.

Title 3.6 Wood-heating venting and safety

Wood heating is a popular and effective auxiliary heating source for homes. However, wood stoves and fireplaces can cause indoor-air-pollution and fire hazards. As part of health and safety work, it’s important to inspect wood stoves to assess potential hazards.

Stoves that are listed by a testing agency like Underwriters Laboratory have a tag stating their clearance from combustibles. Unlisted stoves should conform to the minimum clearances shown here. Ventilated wall protectors, described in NFPA codes and standards, generally allow the listed clearance to be reduced by half. See “Venting combustion gases” on page 109.

All components of wood-stove venting systems should be approved for use with wood stoves. Chimney sections penetrating floor, ceiling, or roof should have approved thimbles, support packages, and ventilated shields to protect combustible materials from high temperatures.

- Inspect stove, vent connector, and chimney for correct clearances from combustible materials as listed in NFPA 211. Ensure that stove is sitting on a noncombustible floor.
- Inspect vent connector and chimney for leaks, and seal leaks with a high-temperature sealant designed for use with metal or masonry.
- Inspect chimney and vent connector for creosote build-up, and clean chimney if creosote build-up exists.
- Inspect the house for soot on seldom-cleaned horizontal surfaces. If soot is present or if the blower door indicates leakage, inspect and replace the gasket on the wood-stove door if appropriate. Seal other air leaks, and take steps to
improve draft as necessary, to reduce indoor smoke emissions.

- Inspect and clean stack damper and/or combustion air intake if necessary.
- Check catalytic combustor for repair or replacement if the wood stove has one.
- Assure that heat exchanger surfaces and flue passages within the wood stove are free of accumulations of soot or debris.

Wood-stove installation: Wood-stove venting and clearances are vitally important to wood-burning safety. Read and follow all manufacturer’s instructions for the stove and its venting components.
Combustion appliances need a source of combustion air while they are operating. The exception to this rule is sealed-combustion or direct-vent appliances, which bring in their own outdoor air through a dedicated pipe. Common combustion-air and venting problems, combined with the complexity of codes and recommendations on combustion air argue strongly in favor of installing direct-vent appliances.

A combustion-air source must deliver between 17 cfm and 600 cfm. The lower end of this scale represents small furnaces and space heaters, and the upper end represents wood-burning fireplaces or large boilers in multifamily buildings.

Table Title-10: CFM Requirements for Combustion Furnaces or Boilers

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Combustion Air (cfm)</th>
<th>Dilution Air (cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Oil</td>
<td>38</td>
<td>195</td>
</tr>
<tr>
<td>Flame-Retention Oil</td>
<td>25</td>
<td>195</td>
</tr>
<tr>
<td>High-Efficiency Oil</td>
<td>22</td>
<td>–</td>
</tr>
<tr>
<td>Conventional Atmospheric Gas</td>
<td>30</td>
<td>143</td>
</tr>
<tr>
<td>Fan-Assisted Gas</td>
<td>26</td>
<td>–</td>
</tr>
<tr>
<td>Condensing Gas</td>
<td>17</td>
<td>–</td>
</tr>
<tr>
<td>Fireplace (no doors)</td>
<td>100–600</td>
<td>–</td>
</tr>
<tr>
<td>Airtight Wood Stove</td>
<td>10–50</td>
<td>–</td>
</tr>
</tbody>
</table>

The goal of assessing combustion air is to verify that there is an adequate supply, and to ensure that a combustion-air problem isn’t creating CO or interfering with combustion.
A combustion appliance zone (CAZ) is an area containing one or more combustion appliances. Combustion appliance zones are classified as either un-confined spaces or confined spaces. Un-confined spaces are open or connected to enough building volume and air leakage to provide combustion air. For un-confined spaces, combustion air comes from leaks within the combustion zone. Confined spaces are combustion zones with a closed door and sheeted walls and ceiling that create an air barrier between the appliance and other indoor spaces. For confined spaces, combustion air must come from outside the combustion zone. A relatively airtight home is itself a confined space and must bring combustion air in from outdoors.

Combustion air is supplied to the combustion appliance in four ways.

1. To an un-confined space through leaks in the building.
2. To a confined space through an intentional opening or openings between the CAZ and other indoor areas where air leaks replenish combustion air.
3. To a confined space through an intentional opening or openings between the CAZ and outdoors or ventilated intermediate zones like attics and crawl spaces.
4. Directly from the outdoors to the combustion appliance through a duct. Appliances with direct combustion-air ducts are called sealed-combustion or direct-vent appliances.

**Title 4.1 Un-confined-space combustion air**

Combustion appliances located in most basements, attics, and crawl spaces get adequate combustion air from leaks in the building shell. Even when a combustion appliance is located within the home's living space, it usually gets adequate combustion air from air leaks unless the house is airtight or the combustion zone is depressurized. See “CAZ Combustion Safety Test” on page 103.
Title 4.2 Confined-space combustion air

A combustion appliance located in a confined space, surrounded by materials that are relatively effective air barriers, may need a vent connecting it to an adjacent indoor area, a crawl space, or outdoors. A confined space is defined by the IFGC as a room containing one or more combustion appliances that has less than 50 cubic feet of volume for every 1000 Btu per hour of appliance input.

However, the code definition aside, if the mechanical room is connected to adjacent spaces through large air passages like floor-joist spaces, the combustion appliance zone is not actually a confined space even though it has a door separating it from other indoor spaces. This connection between the combustion zone and other spaces could be confirmed by pressure testing. See “Very simple pressure tests” on page 214. On the other hand, if the home is unusually airtight, the combustion zone may be unable to provide adequate combustion air, even when the combustion zone is larger than the minimum confined-space room volume, defined earlier.

Combustion air from adjacent indoor spaces is usually preferred over outdoor combustion air because of the possibility of wind
depressurizing the combustion zone. However, if there is a sheltered outdoor space from which to draw combustion air, this can be a superior choice. Outdoor air is generally cleaner and dryer than indoor air, and a connection to the outdoors makes the confined space less affected by indoor pressure fluctuations.

For every 1,000 Btu/hour input, a combustion-air vent to another indoor space should have a total of 2 square inches (in²) of net free area. Net free area is smaller than actual vent area and takes the blocking effect of louvers into account. Metal grills and louvers provide 60% to 75% of their area as net free area while wood louvers provide only 20% to 25%.

Here is an example of sizing combustion air to another indoor area. The furnace and water heater are located in a confined space. The furnace has an input rating of 100,000 Btu/hour. The water heater has an input rating of 40,000 Btu/hour. Therefore, there should be 280 in² of net free area of vent between the mechanical room and other rooms in the home. ([100,000 + 40,000] ÷ 1,000 = 140 x 2 in² = 280 in²).

**Combustion-air vent location**

In confined spaces or airtight homes where outdoor combustion air is needed, prefer low vents to high ones. A combustion-air vent into an attic may depressurize the combustion zone in some cases because the attic tends to be a depressurized zone where air is being exhausted. Instead, connect the combustion zone to a ventilated crawl space or directly to outdoors. The vent opening should have one square inch (1 in²) of net free area for each 3000 Btu/hour of appliance input.

Choose an outdoor location that is sheltered, where the wall containing the vent isn’t parallel to prevailing winds. Wind blowing parallel to an exterior wall and at a right angle to the vent opening tends to de-pressurize both the combustion-air opening and the CAZ connected to it. Indoors, locate combustion air vents away from water pipes to prevent freezing in cold climates.
Title 4.3 Proprietary combustion-air systems

Any passive combustion-air inlet can potentially depressurize the combustion zone because pressure from wind or stack effect can extract air from the combustion zone instead of supplying air. Several proprietary systems are available that offer superior assurance of adequate combustion air compared to passive vents. These systems are particularly appropriate in confined areas suffering from: stubborn draft problems, combustion-zone depressurization, inadequate combustion-air, or a combination of these problems.

Direct combustion-air supply

Many new combustion appliances are designed for direct outdoor-air supply to the burner. These include most condensing furnaces, manufactured house furnaces, manufactured house water heaters, many space heaters, and some non-condensing furnaces and boilers. Some appliances give installers a choice between indoor and outdoor combustion air. Outdoor combustion air is usually preferable in order to prevent the depressurization problems, combustion-air deficiencies, and draft problems.

Sealed combustion: Sealed combustion appliances draw combustion air in and exhaust combustion by-products, either using a draft fan or by pressure difference created by the fire.
Fan-powered combustion air

At least one company manufactures a proprietary combustion-air system that introduces outdoor air through a fan that sits on the floor and attaches to a combustion-air duct to outdoors.

Direct combustion air supply to oil-fired heaters

Oil furnaces and boilers can be either purchased new or may be retrofitted with a sealed combustion-air and venting system. The burner fan is fitted with an air boot that feeds the burner with outdoor air. The amount of outdoor air fed to the burner is usually regulated by a barometric draft control.

Combustion air combined with power venting

Both gas- and oil-fired heating systems can be supplied with combustion air by proprietary systems that combine power venting with powered combustion-air supply. The combustion air simply flows into the combustion zone from outdoors, powered by the power venter. If the appliance has a power burner, like a gun-type oil burner, a boot may be available to supply combustion air directly to the burner as shown here.

TITLE.5 FORCED-AIR SYSTEM STANDARDS

The overall system efficiency of an oil or gas forced-air heating system is affected by blower operation, duct leakage, balance between supply and return air, and duct insulation levels. Retrofits to the forced-air system generally are more cost-effective than retrofits to the heating unit itself.
Leaks in heat exchangers are a common problem, causing the flue gases to mix with house air. Ask clients about respiratory problems, flue-like symptoms, and smells in the house when the heat is on. Also, check around supply registers for signs of soot, especially with oil heating. All furnace heat exchangers should be inspected as part of weatherization. Consider using one or more of the following 7 general options for evaluating heat exchangers.

1. Look for rust at exhaust ports and vent connector.
2. Look for flame impingement on the heat exchanger during firing.
3. Observe flame movement, change in chimney draft, or change in CO reading as blower is turned on and off.
4. Look for flame-damaged areas near the burner flame.

**Sealed-combustion, oil-heating retrofit:** Direct supply of combustion air to gun-type oil burners is a good option for shielding the oil burner from house pressures.
5. Measure the flue-gas oxygen concentration before the blower starts and just after it has started. There should be no more than a 1% change in the oxygen concentration.

6. Examine the heat exchanger, shining a bright light on one side and looking for light traces on the other using a mirror to peer into tight locations.

7. Employ chemical detection techniques, following manufacturer’s instructions.

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**Heat exchangers with either rust through penetrations or cracks are to be considered non-serviceable and defective.**

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**Title.5.2 Furnace operating standards**

The effectiveness of a furnace depends on its temperature rise and flue-gas temperature. For efficiency you want a low temperature rise and low flue-gas temperature. However, you must maintain a minimum flue-gas temperature to prevent corrosion in the venting. Apply the following furnace-operation standards to maximize the heating system's seasonal efficiency and safety.

- Check temperature rise after 5 minutes of operation. Refer to manufacturer's nameplate for acceptable temperature rise (supply temperature minus return temperature). The temperature rise should be between 40°F and 90°F (or PMI) with the lower end of this scale being preferable for energy efficiency.

- All forced-air heating systems must deliver supply air and collect return air only within the intentionally heated por-
tion of the house. Taking return air from an un-heated area of the house such as an unoccupied basement is not acceptable.

Table Title-11: Furnace Operating Parameters

<table>
<thead>
<tr>
<th>Inadequate temperature rise: condensation and corrosion possible.</th>
<th>Temperature rise OK for both efficiency and avoidance of condensation</th>
<th>Temperature rise excessive fan speed heat exchanger and ducts</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°</td>
<td>45°</td>
<td>70°</td>
</tr>
</tbody>
</table>

Temperature Rise = Supply Temperature – Return Temperature

<table>
<thead>
<tr>
<th>Excellent fan-off temperature if comfort is acceptable.</th>
<th>Borderline acceptable: Consider replacing fan control.</th>
<th>Unacceptable range: Significant savings possible by replacing fan control.</th>
</tr>
</thead>
<tbody>
<tr>
<td>85°</td>
<td>100°</td>
<td>115°</td>
</tr>
</tbody>
</table>

Fan-off Temperature

<table>
<thead>
<tr>
<th>Excellent fan-on temperature range: No change needed.</th>
<th>Fair: Consider fan-control replacement if fan-off temperature is also borderline.</th>
<th>Poor: Replace fan control.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100°</td>
<td>120°</td>
<td>140°</td>
</tr>
</tbody>
</table>

Fan-on Temperature

- The fan-off temperature should be between 90° and 100° F, with the lower end of the scale being preferable for maximum efficiency.
- The fan-on temperature should be no less than 120° F.
- The high-limit controller should shut the burner off before the furnace temperature reaches 200°F.
- On time-activated fan controls, verify that the fan is switched on within two minutes of burner ignition and is switched off within 2.5 minutes of the end of the combustion cycle.

If the heating system does not conform to these standards, consider the following improvements.
✓ Clean or change dirty filters
✓ Clean the blower, increase fan speed, and improve ducted air circulation. See “Improving duct-system airflow” on page 139.
✓ Adjust fan control to conform to the above standards, or replace the fan control if adjustment fails. Many fan controls on modern furnaces aren’t adjustable.
✓ Adjust the high-limit control to conform to the above standards, or replace the high-limit control.

**Adjustable drive pulley:** This adjustable pulley moves back and forth allowing the belt to ride higher or lower, adjusting the blower’s speed.

**Fan/limit control:** Turns the furnace blower on and off, according to temperature. Also turns the burner off if the heat exchanger gets too hot (high limit).

**Title.5.3 Duct air-tightness standards**

Duct air leakage is a major energy-waster in homes where the ducts are located outside the home’s thermal boundary in a crawl space, attic, attached garage, or leaky basement. When the weatherization job will leave these intermediate zones outside the thermal boundary, duct air-sealing is cost-effective.

Ducts should be tested to determine how much they leak before any duct air sealing is performed. For information on duct testing, see “Duct airtightness testing” on page 221.
Duct leakage sites

Ducts located outside the thermal boundary or in an intermediate zone like a ventilated attic or crawl space should be sealed. The following is a list of duct-leak locations in order of their relative importance. Leaks nearer to the air handler see higher pressure and are more important than leaks further away.

✓ First, seal all return leaks within the combustion zone to prevent this leakage from depressurizing the combustion zone and causing backdrafting.

✓ Plenum joint at air handler: These joints may have been difficult to fasten and seal because of tight access. Go the extra mile to seal them airtight by caulking this important joint even if it requires cutting an access hole in the plenum. (Avoid mastic and fabric mesh here for future access—furnace replacement, for example.)

✓ Joints at branch takeoffs: These important joints should be sealed with a thick layer of mastic. Fabric mesh tape is a plus for new installations or when access is easy.

✓ Joints in sectioned elbows: Known as gores, these are usually leaky.

✓ Tabbed sleeves: Attach the sleeve to the main duct with 3-to-5 screws and apply mastic plentifully.

✓ Flexduct-to-metal joints: Apply mastic to the metal sleeve. Clamp the flexduct’s inner liner over this strip of mastic with a plastic strap, using a strap tensioner. Clamp the insulation and outer liner with another strap.

✓ Support ducts and duct joints with duct hangers where needed.

✓ Seal leaky joints between building materials composing cavity-return ducts, like panned floor cavities and furnace return platforms.
Flexduct joints: Flexduct itself is usually fairly airtight, but joints, sealed improperly with tape, can be very leaky. Use methods shown here to make flexduct joints airtight.

- Seal leaky joints between supply and return registers and the floor, wall, and ceiling to which they are attached.
- Consider sealing off supply and return registers in unoccupied basements.
- Seal penetrations made by wires or pipes traveling through ducts. Even better: move the pipes and wires and patch the holes.

Panned floor joists: These return ducts are often very leaky and may require removing the panning to seal the cavity.
Materials for duct air-sealing

Duct mastic is the preferred duct-sealing material because of its superior durability and adhesion. Apply at least $\frac{1}{16}$-inch thick and use reinforcing mesh for all joints wider than $\frac{1}{8}$ inch or joints that may experience some movement.

Siliconized acrylic-latex caulk is acceptable for sealing joints in panned joist spaces, used for return ducts.

Joints should rely on mechanical fasteners to prevent joint movement or separation. Tape should never be expected to hold a joint together nor expected to resist the force of compacted insulation or joint movement. Aluminum foil or cloth duct tape are not good materials for duct sealing because their adhesive often fails after a short time.

Title.5.4 Duct insulation

Insulate supply ducts that run through unconditioned areas outside the thermal boundary such as crawl spaces, attics, and attached garages with a minimum of R-11 vinyl- or foil-faced duct insulation. Don’t insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer. Follow the best practices listed below for installing insulation.

- Always perform necessary duct sealing before insulating ducts.
- Insulation should cover all exposed supply ducts, without significant areas of bare duct left uninsulated.
• Insulation should be fastened by mechanical means such as stick pins, twine, or plastic straps. Tape can be effective for covering joints in the insulation to prevent air convection, but tape will usually fail if expected to resist the force of the insulation’s compression or weight.

Title.5.5 Improving duct-system airflow

Inadequate airflow is a common cause of comfort complaints. The airflow capacity of the air handler may be evaluated in relationship to the capacity of the furnace or air conditioner. For combustion furnaces, the heat exchanger air flow should be adjusted to manufacturer's specifications. Central air conditioners and heat pumps should deliver 400 cfm of airflow per ton of cooling capacity. See “Furnace replacement” on page 144 for more information about evaluating airflow.

When the air handler is on there should be a strong flow of air out of each supply register, providing its balancing damper is properly adjusted. Low airflow may mean that a branch is blocked or separated, or that return air is not sufficient. When low airflow is a problem, consider the following obvious improvements.

✓ Clean or change filter.
✓ Clean furnace blower.
✓ Clean air-conditioning or heat pump coil. (If the blower is dirty, the coil is probably also dirty).
✓ Increase blower speed.
✓ Lubricate blower motor (PMI), and check tension and condition of drive belt and the condition of motor and blower pulleys.

✓ Repair or replace bent, damaged, or restricted registers.

Filter and blower maintenance

A dirty filter can reduce airflow significantly. Take action to prevent filter-caused airflow restriction by the following steps:

• Insure that filters are easy to change or clean.

• Stress to the client the importance of changing or cleaning filters, and suggest to the client a regular filter-maintenance schedule.

• Clean the blower. This task involves removing the blower and removing dirt completely with a brush or water spray.

• Special air-cleaning filters offer more resistance than standard filters, especially when saturated with dust. Avoid using them, unless you test for airflow after installation.

Furnace filter location: Filters are installed on the return-air side of forced air systems. Look for them in one or more of the following places.
Duct improvements to increase airflow and improve comfort

Consider the following improvements in response to customer complaints and conditions you observe during a thorough duct inspection. Unbalanced airflow through ducts can pressurize or depressurize rooms, leading to increased air leakage through the building shell. For information on how to test these room pressures, see “Measuring duct-induced pressures” on page 223. Consider the following duct changes to increase system airflow and reduce the imbalance between supply and return.

- Remove obstructions to registers and ducts such as rugs, furniture, and objects placed inside ducts, like children’s toys and water pans for humidification.
- Remove kinks from flex duct, and replace collapsed flex duct and fiberglass duct board.
- Install additional supply ducts and return ducts as needed to provide conditioned air throughout the building, especially into additions to the building.
- Undercut bedroom doors, especially in homes with single return registers.
- Install a transfer grille between the bedroom and main body of house to improve airflow.
- Retrofit jumper ducts, composed of one register in the bedroom, one register in the central return-air zone, and a duct in between (usually running through an attic or crawl space).
- Install registers and grilles where missing.
New ducts should not be installed in unconditioned spaces unless absolutely necessary. If ducts are located in unconditioned spaces, joints should be sealed and the ducts insulated as described previously. See “Duct air-tightness standards” on page 135 and “Duct insulation” on page 138.

New ducts must be physically connected to the existing distribution system or to the furnace. Install balancing damper in each new branch duct. Registers should terminate each new supply or return branch duct.

**Restricted return air:** Return air is often restricted, requiring a variety of strategies to relieve the resulting house pressures and low system airflow. Installing an additional return duct directly into the air handler is a preferred strategy.

**New ducts**

New ducts should not be installed in unconditioned spaces unless absolutely necessary. If ducts are located in unconditioned spaces, joints should be sealed and the ducts insulated as described previously. See “Duct air-tightness standards” on page 135 and “Duct insulation” on page 138.

New ducts must be physically connected to the existing distribution system or to the furnace. Install balancing damper in each new branch duct. Registers should terminate each new supply or return branch duct.

**TITLE.6 HEATING-SYSTEM REPLACEMENT SPECIFICATIONS**

All heating replacement systems must have dedicated combustion air whenever possible. Don't assume that older furnaces and boilers are inefficient until testing them. During testing, make appropriate efforts to repair and adjust the existing fur-
nace or boiler, before deciding to replace it. Replacement parts like gas valves and controls for older heating units are commonly available.

Heating appliances are often replaced when the cost of repairs and retrofits exceeds one half of estimated replacement costs. Estimate the repair and retrofit costs and compare them to replacement cost before deciding between retrofit and replacement.

Replacements should only be considered if repairs are impractical or expensive or if a replacement shows a savings to investment ratio (SIR) of 1.0 or better as modeled by NEAT. Replacement should be considered if existing furnace falls outside of the PA parameters for health, safety and efficiency.”

New heating appliances must be installed to manufacturer’s specifications or current code requirements, whichever is more stringent, and follow all applicable building and fire codes. Replacement gas heating appliances should have a minimum Annual Fuel Utilization Efficiency (AFUE) of 90% and be installed as a two-pipe direct-vent or concentric flue system for exhaust and combustion air. Combustion air must be derived from outdoors. These high-efficiency furnaces are direct-vent, sealed-combustion units with health and safety benefits in addition to their superior efficiency and significantly lower fuel usage. Boilers and oil-fired units must have a minimum AFUE of 82%.

Heat load calculations, used to size the new heater, should account for reduced heating loads, resulting from insulation and
air-sealing work. Heat load calculations should follow Manual J procedures.

Specifications are presented here first according to fuel-type—oil or gas—then by distribution type: forced air, hot water, or steam.

**Title.6.1 Furnace replacement**

The overall goal of furnace replacement is to provide a forced-air heating system in virtually new condition, even though existing supply and return ducts may remain. Any design flaws in the ducts and registers should be diagnosed and corrected during the furnace replacement.

Observe the following standards in furnace installation.

Furnace should be sized to the approximate heating load of the home, accounting for post-weatherization heat-loss reductions.

- Installer should add return ducts or supply ducts as part of furnace replacement to improve air distribution, to eliminate duct-induced house pressures, and to establish acceptable values for static pressure and temperature rise.

- Supply and return plenums should be mechanically fastened with screws and sealed to air handler with mastic and fabric mesh tape to form an essentially airtight connection on all sides of these important joints.

- All ducts should be sealed as described in “Duct air-tightness standards” on page 135.
✓ Temperature rise (supply temperature minus return temperature) must be within manufacturer’s specifications or no higher than 90° F.

✓ High limit should stop burner operation within 10% of manufacturer’s high limit. Furnace must not cycle on high limit.

80+ gas furnace: An 80+ furnace has a restrictive heat exchanger, an inducer, and has no draft diverter or standing pilot.

90+ gas furnace: A 90+ furnace has a condensing heat exchanger and an inducer for pulling combustion gases through its more restrictive heat exchange system and establishing a strong positive draft.

✓ Fan control should be set to activate fan at no less than 120° F and deactivate it at 90° to 100° F. Slightly higher settings are acceptable if these recommended settings cause a comfort complaint.
Static pressure, measured in both supply and return plenums should be within manufacturer's specifications.

Blower should not be set to operate continuously.

Seal holes through the jacket of the air handler with mastic or foil tape.

Filters should be held firmly in place and provide complete coverage of blower intake or return register. Filters should be easy to replace.

Title.6.2 Oil-fired heating installation

The overall goal of the system replacement is to provide an oil-fired heating system in virtually new condition, even though components like the oil tank, chimney, piping, or ducts may remain. Any maintenance or repair on these remaining components should be considered part of the job. Any design flaws related to the original system should be diagnosed and corrected during the heating-system replacement.

Examine existing chimney and vent connector for suitability as venting for new appliance. The vent connector may need to be re-sized and the chimney may need to be re-lined.

Check clearances of heating unit and its vent connector to nearby combustibles, by referring to NFPA 31.
✓ Check for the presence of a control that will interrupt power to the burner in the event of a fire.
✓ Test oil pressure to verify compliance with manufacturer’s specifications.
✓ Test transformer voltage to verify compliance with manufacturer’s specifications.

✓ Install digital double set-back thermostat, if possible.
✓ Adjust oxygen, flue-gas temperature, and smoke number to match manufacturer’s specifications.
✓ Install new fuel filter and purge fuel lines as part of new installation.
✓ Bring tank and oil lines into compliance with NFPA 31, Chapters 2 and 3.
✓ Check for emergency shut-off, installed in the living space.
✓ See “Combustion Standards for Oil-Burning Appliances” on page 96.
Title 6.3 Gas-fired heating installation

The overall goal of the system replacement is to provide a gas-fired heating system in virtually new condition, even though existing components like the gas lines, chimney, water piping, or ducts may remain. Any necessary maintenance or repair on these remaining components should be considered part of the installation. Any design flaws in the original system should be diagnosed and corrected during the heating-system replacement.

The new furnace should have an Annual Fuel Utilization Efficiency (AFUE) of at least 90%.

- Check clearances of heating unit and its vent connector to nearby combustibles, according to the International Fuel Gas Code (IFGC). See “Venting and Combustion Air Standards” on page 110 for more information about National Fire Protection Association (NFPA) Standards.

- Clock gas meter to insure correct gas input. See “Measuring BTU input on natural gas appliances” on page 92.

- If necessary, measure gas pressure, and increase or decrease gas pressure to obtain proper gas input.

- Test gas water heater to insure that it vents properly after installation of a sealed-combustion, 90+ AFUE furnace. If necessary power vent, rel ine chimney, move or replace water heater to assure proper venting.

- Install digital double set-back thermostat, if possible.

- Follow manufacturer’s venting instructions along with the IFGC to establish a proper venting system.

- Ensure proper sediment trap (drip leg) on gas line.

- Ensure that the new heating appliance meets specifications on page 91.

- Ensure that the new unit is properly sized as per ACCA Manual J protocols.
Title.6.4 Electric-furnaces and electric baseboard heat

The purpose of servicing electric furnaces and electric baseboard heat is to clean the heat exchangers and blower. Sealing ducts is also very important.

✓ Check and clean thermostat.
✓ Clean and lubricate blower if appropriate.
✓ Clean or replace all filters.
✓ Vacuum and clean housing around electric elements, if dirty.
✓ Clean fins on electric-baseboard systems, if applicable.
✓ Take extra care in duct sealing and duct airflow improvements for electric furnaces because of the high cost of electricity. See “Duct air-tightness standards” on page 135 and “Improving duct-system airflow” on page 139.
✓ Verify that safety limits, temperature rise, and static pressure conform to manufacturer’s specifications.

Title.7 Hot-water and steam standards

The following standards refer to hot-water and steam systems commonly found in single-family homes. Hot-water and steam systems found in multifamily buildings are generally more complex and should be tested and evaluated by professionals experienced in their operation.

Title.7.1 Boiler efficiency and maintenance

Boilers can maintain good performance and efficiency for many years if they are regularly maintained and tuned-up. Boiler performance and efficiency improve after effective maintenance and tune-up procedures. There are more ways for performance and efficiency to deteriorate in boilers compared to furnaces.
Specifically these are:

- Corrosion, scaling, and dirt on the water side of the heat exchanger.
- Corrosion, dust, and dirt on the fire side of the heat exchanger.
- Excess air during combustion from air leaks and incorrect fuel-air mixture.
- Off-cycle air circulation through the firebox and heat exchanger, removing heat from stored water.

Consider the following maintenance and efficiency improvements for both hot-water and steam boilers.

✓ Check for leaks on the boiler, around its fittings, or on any of the distribution piping connected to the boiler.

✓ Clean fire side of heat exchanger of noticeable dirt.

✓ Check doors and cleanout covers for air leakage. Replace gaskets or replace warped doors or warped cleanout covers.

✓ Drain water from the boiler drain until the water flows clean on steam boilers only!
Title 7.2 Hot-water space-heating

Hot-water heating is generally a little more efficient than forced-air heating and considerably more efficient than steam heating. The most significant energy problems in hot-water systems are poor steady-state efficiency, off-cycle flue losses robbing heat from stored water, and boilers operating at too high a water temperature.

Consider the following safety checks and improvements.

- Confirm the existence of a 30-psi-rated pressure-relief valve for hot-water, and a 15-psi-rated pressure relief valve for steam boilers. Replace a malfunctioning valve or add one if none exists. Note signs of leakage or discharges, and find out why the relief valve is discharging.

**Note:** You can recognize a hot-water boiler by its expansion tank, located somewhere near the boiler. This cylindrical tank provides an air cushion to allow the system’s water to expand and contract as it is heated and cooled without discharging through the relief valve.

- Make sure that the expansion tank isn’t waterlogged or sized too small for the system.

- If rust is observed in venting, verify that return water temperature is above 130°F for gas and above 150°F for oil, to prevent acidic condensation.

- High-limit control should deactivate burner between 180° and 200°F on boilers without a domestic coil.

Cast-iron sectional boilers: The most common boiler type for residential applications.
✓ Lubricate circulator pump(s) if necessary.

Consider the following efficiency improvements.

✓ Repair water leaks in the system.

✓ Boiler should not have low-limit control for maintaining a minimum boiler-water temperature, unless the boiler is heating domestic water in addition to space heating.

✓ Bleed air from radiators and piping through air vents on piping or radiators on hot water systems. Most systems have an automatic fill valve. If there is a manual fill valve for refilling system with water, it should be open to push water in and air out, during air purging on hot water systems.

✓ Consider installing outdoor reset controllers on larger boilers to regulate water temperature, depending on outdoor temperature.

✓ After control improvements like two-stage thermostats or reset controllers, verify that return water temperature is high enough to prevent condensation and corrosion in the boiler and flue as noted previously.

✓ Vacuum and clean fins of fin-tube convectors if you notice dust and dirt there.

✓ Insulate all supply piping, passing through unheated
areas, with foam pipe insulation, at least one-inch thick, rated for temperatures up to 200° F.

✓ Consider installing electric vent dampers on atmospheric gas- and oil-fired high-mass boilers.

**Title.7.3 Steam heating**

Steam heating systems should operate at the lowest steam pressure that will heat the building. This may be considerably less than 1 psi on the boiler-pressure gauge. Large buildings may need higher steam pressures, but smaller structures or buildings can operate at lower steam pressures. Traps and air vents are crucial to operating at a low steam pressure. Electric vent dampers will reduce off-cycle losses for both gas- and oil-fired systems.

**One-pipe and two-pipe steam systems:** Still common in multifamily buildings, one-pipe steam works best when very low pressure steam can drive air out of the piping and radiators quickly through plentiful vents. Vents are located on each radiator and also on main steam lines.

**Two-pipe steam systems:** Radiator traps keep steam inside radiators until it condenses. No steam should be present at the receiver or receiver and pump if the system is so equipped.
Perform the following for safety and maintenance checks on steam systems.

- Verify that steam boilers are equipped with high-pressure limits and low-water cut-off controls.
- Verify that flush valves on low water cutoffs are operable and do not leak.
- On steam boilers with externally mounted low water cutoffs, verify the function of the control by flushing the low water cutoff with the burner operating. Combustion must cease when the water level in the boiler drops below the level of the float.
- Drain water out of blow-down valve until water runs clear.
- Check with owner about chemicals added to boiler water to prevent corrosion and mineral deposits. Add chemicals if necessary.
- Ask owner about instituting a schedule of blow-down and chemical-level checks.

Consider the following efficiency checks and improvements for steam systems.

- Verify that high-pressure limit control is set at or below 1 (one) psi.
- Verify steam vents are operable and that all steam radiators receive steam during every cycle. Replace vents as necessary. Add vents to steam lines and radiators as needed to achieve this goal.

**Note:** You can recognize a steam boiler by its sight glass, which will indicate the boiler’s water level. Notice that the water doesn’t completely fill the boiler, but instead allows a space for the steam to form above the boiler’s water.
✓ Check steam traps with a digital thermometer or listening device to detect any steam escaping from radiators through the condensate return. Replace leaking steam traps or their thermostatic elements.

✓ Repair leaks on the steam supply piping or on condensate return piping.

✓ Consider a flame-retention burner and electric vent damper as retrofits for steam boilers.

✓ Clean fire side of heat exchanger of noticeable dirt.

✓ All steam piping, passing through unconditioned areas, should be insulated to at least R-3 with fiberglass or specially designed foam pipe insulation rated for steam piping.

Steam traps: Steam enters the steam trap heating its element and expanding the fluid inside. The expanded element plugs the steam’s escape with a valve.
Don’t assume that a boiler replacement will save much energy unless the boiler’s steady-state efficiency can’t be raised to around 80%. The overall goal of boiler replacement is to provide a hydronic heating system in virtually new condition, even though existing supply and return piping may remain. Any design flaws in the venting, piping, and controls should be diagnosed and corrected during the boiler replacement.

Boiler piping and controls present many options for zoning, boiler staging, and energy-saving controls. Dividing homes or multifamily buildings into zones, with separate thermostats, can significantly improve energy efficiency over operating a single zone. Modern hydronic controls can provide different water temperatures to different zones with varying heating loads.

The new gas boiler should have an AFUE of at least 80%. The new boiler should be equipped with electronic ignition and a draft-assisting or power-draft fan. It should not have a draft diverter.

Cast-iron sectional boilers: Are the most common boilers for residential applications.
Boiler seasonal efficiency is more sensitive to proper sizing than is furnace efficiency. A boiler should be sized to the load of the structure. Consider the following specifications when replacing boilers.

- Inspect chimney for deterioration and correct sizing. Repair and re-line the chimney as necessary.
- An effective air-eliminating device or devices must be part of the new hydronic system.
- Install the pump near the downstream side of the pressure tank to prevent the suction side of the pump from depressurizing the piping, which can pull air into the piping.
- The expansion tank should be replaced, unless it is verified to be the proper size for the new system and tested for correct pressure during boiler installation.
- Verify that return water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation within the boiler, unless the boiler is designed for condensing. Install piping bypasses, mixing valves, primary-secondary piping, or other strategies, as necessary, to prevent condensation within a non-condensing boiler.
- Recognize the boiler installation’s potential for causing condensation in the vent connector and chimney. If the boiler’s steady-state efficiency is expected to be more than 83%, condensation-resistant venting and condensation drains should be designed into the venting system. These custom venting systems are provided or specified by the manufacturer.
✓ A pressure-relief valve must be installed with the new boiler and connected to a discharge pipe, terminating at a location approved by code.

✓ Maintaining a low-limit boiler-water temperature is wasteful. Boilers should be controlled for a cold start, unless the boiler is used for domestic water heating.

✓ Insulate all supply piping, outside conditioned spaces, with foam or fiberglass pipe insulation.

**Simple reverse-return hot-water system:** The reverse-return method of piping is the simplest way of balancing flow among heat emitters.
✓ Extend new piping and radiators to conditioned areas like additions and finished basements, currently heated by space heaters.

✓ For large boilers, consider installing outdoor reset controllers to adjust supply water temperature according to outdoor temperature.

✓ For large boilers, consider installing a cutout controller that prevents the boiler from firing when the outdoor temperature is above a certain setpoint where heat is not needed.

**Reset controller:** The circulating water is controlled by the reset controller according to the outdoor temperature.

![Diagram of a heating system with reset controller, outdoor sensor, aquastat, and boiler-water temperature sensor.](image)
A building’s thermal boundary consists of an air barrier and insulation which must be in continuous contact with each other. The thermal boundary should surround occupied or unoccupied conditioned space but it may include unconditioned spaces such as where the heating system is located. These measures improve the building’s thermal boundary.

Perform air leakage testing and evaluation before beginning air-sealing or insulation work. See “Diagnosing Shell & Duct Air Leakage” on page 199.

Use visual inspection to determine the cost-effectiveness of adding thermal resistance to a building. Reducing air leakage and adding insulation use the same general approach—the most critical areas are retrofitted first and then less needy areas are retrofitted as time and budget permit.

Air-sealing may also be undertaken to reduce the flow of moisture into building cavities. Evaluate all insulation and air sealing measures using the PA WAP Single Family Home Measure Selection Priority List on page 19.

**Title.1 Reducing air leakage**

Air leakage in homes accounts for up to 40% of annual heating costs. Air-leakage reduction is one of weatherization’s most important functions, and often the most difficult.

The primary goals of air-leakage reduction are to:

1. Avoid moisture migration into building cavities
2. Protect insulation’s thermal resistance
3. Increase comfort
4. Save energy
Air travels into and out of the building by three main pathways:

1. Bypasses, which are significant flaws in the home’s air barrier.
2. Seams between building materials.
3. The building materials themselves.

Before air sealing, be aware of all indoor air-quality issues and house-pressure hazards. State and local governments may set standards for airtightness levels and ventilation. See “Building Airflow Standard (BAS)” on page 207.

**Thermal boundary flaws:** The thermal boundary contains the air barrier and insulation that should be adjacent to and in continuous contact with each other. The insulation and the air barrier are often discontinuous at corners and transitions.

### Title.1.1 When not to air seal

Perform no air-sealing when there is obvious threat to the occupants health, the installers health, the building’s durability, or to the effectiveness of the air-sealing materials. See “Health and Safety Information” on page 63 for more information. Do not air
seal when the following conditions are present or until they have been corrected:

1. Moisture has caused structural damage, rot, mold or mildew growth.
2. Fire hazards place the building’s life and occupant safety in jeopardy.
3. Measured carbon monoxide level exceeds suggested action level.
4. Chimney drafts of combustion appliances don’t meet minimum standards.
5. A permanently mounted unvented fossil fuel fired heater is used as a primary heating source.
6. The building is already at or below its Building Airflow Standard, and no mechanical ventilation exists or is planned.
7. The client indicates that they intend to use portable fossil-fuel-fired heaters.

**Title 1.2 Sealing bypasses**

Major air sealing includes sealing bypasses and other relatively large openings between the conditioned and unconditioned space. Major air sealing activities are generally completed prior to other shell measure activities, and usually result in a significant drop in the blower door reading and/or changes in pressure diagnostics readings.
Bypasses will often be found between the conditioned space and intermediate zones such as floor cavities, attics, crawl spaces, attached garages, and porch roofs. The time and effort you spend to seal a bypass should depend on its size. For information on measuring and locating air leaks, see “Using a manometer to test air barriers” on page 215.

It is always preferable to use strong air-barrier materials like plywood or drywall to seal bypasses, particularly in regions with strong winds. These materials should be attached with mechanical and/or adhesive bonds. Air barriers must be able to resist severe wind pressures.

Bypasses are not always easily accessible. When they are not easily accessible, technicians sometimes blow densely packed cellulose insulation into surrounding cavities, hoping that the cellulose will resist airflow and plug cracks between building materials.

The following are examples of bypasses and how to seal them. All bypasses are to be sealed prior to insulating except where cellulose is also being used to seal bypasses.
Joist spaces under kneewalls in finished attic areas: Connect knee-wall with the plaster ceiling of the floor below by creating a rigid seal under the kneewall. See page 177 for specific techniques.

Kitchen or bathroom interior soffits: Seal the top of the soffit with fire-rated foil faced foam board, plywood or drywall, fastened and sealed to ceiling joists and soffit framing.

Kitchen soffits: These framing flaws are often open to both the wall cavity and ventilated attic. Any hole in the soffit creates a direct connection between the kitchen and attic.

Two-level attics in split-level houses: Seal the wall cavity with a rigid material fastened to studs and wall material.

Soil stacks, plumbing vents, open plumbing walls: Seal joints with expanding foam or caulk. If joint is too large, stuff with fiberglass insulation, and spray foam over the top to seal the surface of the plug.
Chimney, fireplace: Seal chimney and fireplace bypasses with sheet metal (minimum 28 gauge thickness). Seal to chimney or flue and ceiling structure with a high temperature sealant or chimney cement.

Tops and bottoms of balloon-framed interior partition wall cavities, missing top plates: Seal with a fiberglass insulation plug, covered with a 2-part foam air-seal. Seal with rigid barrier, like 1/4-inch plywood or 1-inch foam board sealed to surrounding materials with caulk or liquid foam.

Balloon-framed interior walls: These wall cavities can be open to both the attic and basement.
Housings of exhaust fans and recessed lights: Caulk joints where housing comes in contact with the ceiling with high-temperature silicone sealant.

Duct boots and registers: Caulk or foam joint between duct boot and ceiling, wall, or floor finish if ducts are located in attic, crawl space, or attached garage.

Wiring and conduit penetrations: Tradesmen often knock large holes in concrete walls without patching them. These can create large air leaks. Seal penetration with caulk or foam.

Duct chases: If chase opening is large, seal with a rigid barrier such as fire-rated foam board, plywood or drywall, and seal the new barrier to ducts with caulk or foam. Smaller cracks between the barrier and surrounding materials may be foamed or caulked.

Bathtubs and shower stalls: Seal holes and cracks from underneath with expanding foam. Seal large openings with rigid materials caulked or foamed at edges.

Attic hatches and stairwell drops: Weatherstrip around doors and hatches. Caulk around frame perimeter. See “Manufactured retractable-stair cover” on page 180.
Other openings in the air barrier: Seal with rigid material, caulk, spray foam, or expanding foam depending upon size and nature of opening.

Pocket Door Wall Cavity: When located on the second floor, cap the top of the entire wall cavity in the attic with rigid board, caulked and stapled. Where wall cavities containing the retracted pocket door halves connect with exterior framed walls, stuff narrow strips of unfaced fiberglass batts into the door opening with a broom handle far enough to allow for complete opening of the door.

Pocket doors: Care should be taken that insulation and air sealing procedures do not hinder the operation of the door.
Title.1.3 Minor air sealing

- Cracks in exterior window and door frames can be sealed to keep water out. If the crack is deeper than $\frac{5}{16}$-inch, it must be backed with a material such as backer rod and then sealed with caulk. Any existing loose or brittle material should be removed before the crack is re-caulked.

- Joints in sill plate (mud sill) and around utility openings in foundation should be sealed.

- Holes and cracks in masonry surfaces can be sealed with a cement-patching compound or mortar mix.

- Interior joints can be caulked if blower-door testing indicates substantial leakage. These joints include where baseboard, crown molding and/or casing meet the wall/ceiling/floor surfaces. Gaps around surface-mounted or recessed light fixtures and ventilation fans should also be caulked if appropriate.

**Title.2 Installing Insulation**

The building shell’s thermal resistance is increased by adding insulation. Insulation reduces heat transmission. Combined with the home’s air barrier, insulation forms the thermal boundary. Make sure that the air barrier and insulation will be aligned using procedures outlined in “Zonal pressure diagnostics” on page 211.
Insulation should cover the entire area intended for insulation without voids or edge gaps. Blown insulation should be installed at sufficient density to resist settling, according to manufacturer’s instructions. Insulation should be protected from air movement by an effective air barrier. Insulation should be protected from moisture.

Wall cavities should be filled with high-density insulation, from top to bottom and side to side. Observe lead-safe weatherization practices with all tasks that may disturb interior paint. See “Lead-safe weatherization” on page 76. The retrofitted depth of attic insulation or floor insulation should be determined by the PA Weatherization Priority List or the NEAT computer audit.

**Title.2.1 Electrical safety**

Comply with the following fire and electrical safety procedures before insulating.

- An electrical survey will be completed on any building component where insulation work is to be performed.

- Attic and ceiling cavities, between conditioned and unconditioned space, will be inspected for knob and tube, non-metallic sheathed (NM), and armored (BX) cable.

- Any cavities that do not contain Knob-and-Tube wiring or other unsafe wiring conditions can and should be insulated as per the PA WAP protocols.

- Loose fill insulation shall not be installed over or encapsulate any knob and tube wiring. This includes any combination of wiring practices as well as any associated splice joints.
✓ Loose fill insulation, fiberglass batt or rigid board insulation may be installed up to or under the knob-and-tube wiring as to avoid encapsulating the wiring.

✓ Air sealing may be performed on the building shell but should not come in contact or encapsulate open wiring splices.

✓ All junction boxes shall be covered with steel covers designed for the size, type and intended use.

✓ Identify the location of all covered junction boxes. On floored attics, mark directly on the floor. On unfloored attic areas use a wire and flag.

✓ Identify the circuit that powers the area where the insulation work is to be preformed and install appropriately sized S-type fuses.

Observe these safety guidelines for light fixtures.

✓ Locate all ceiling fixtures in the attic and visually inspect the wiring connected to the fixture, fixture box or connecting fitting. If insulation appears brittle or damaged do not allow insulation to come in contact with the fixture inches from the fixture.

Covering recessed light fixtures: Covering recessed light fixtures with fire-rated 5/8” drywall or sheet-metal enclosures reduces air leakage and allows insulation to be blown around the box.

✓ Recessed light fixtures that are not IC (insulation contact) rated must be covered with a box built from 5/8” fire-rated
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Drywall board or unfaced duct board material to maintain a clearance of 3”.

- Identify the location of all covered light fixture junction boxes. On floored attics, mark their location directly on the floor. On unfloored attic areas use a wire and flag.

**Title.2.2 Attic insulation**

Air leakage testing and air sealing should always precede attic insulation because attic insulation is not itself an air barrier – it needs an air barrier adjacent to it to be effective. Air moving through insulation reduces its R-value and can deposit moisture in the insulation. See “Zonal pressure diagnostic methods” on page 216 and “Sealing bypasses” on page 163 for more information.

**Preparation for attic insulation**

Observe the following important preparatory steps before installing attic insulation:

- OSHA-approved respirators or dust masks should be worn while blowing insulation or installing batts. See “Respiratory health” on page 81 for more information.

- Repair all roof leaks before insulating attic. If the roof leaks or can’t be repaired, don’t insulate the attic.

- All kitchen and bath fans must be vented outdoors through roof or soffit fittings. Fans without operating backdraft dampers should be retrofitted with backdraft dampers, or the fan should be replaced. Check new fans for proper damper operation. Use PVC, rigid metal, or gal-
vanized pipe for venting whenever possible, and insulate the pipe to prevent condensation. Do not use flexible plastic ducting.

- Install collars or dams around masonry chimneys, B-vent chimneys, and manufactured chimneys after sealing bypass.

- All-fuel wood-stove chimneys should have ventilated insulation shields to prevent insulation from touching the chimney.

- If you plan to cover an electrical junction box with insulation, mark its location with a sign or other means.

- If sheet metal is used as a barrier around heating producing devices or chimneys, it must be fastened securely to the ceiling joist so the barrier won’t collapse. Barriers should extend at least 4 inches above the insulation and be secured to keep insulation a minimum of 3 inches away from the heat-producing device.

- If insulation is to cover wiring, inspect fuse boxes to ensure that wiring isn’t overloaded.

- Knob-and-tube wiring should not be covered with retrofit insulation.

- Install S-type fuses where appropriate to prevent circuit overloading. Maximum ampacity for 14-gauge wire is 15 amps and for 12-gauge wire is 20 amps.

- Install chutes, dams, tubes, or other blocking materials to prevent blown insulation from plugging air channels between soffit vents and the attic. These chutes or other devices maximize the amount of insulation that may be
installed over top plates, and help to prevent wind-washing of the insulation by cold air entering soffit vents.

**Chute or dam:** Prevents wind washing and airway blockage by blown insulation.

✔ Before insulating the attic, seal bypasses as described previously. Air leakage and convection can significantly degrade the thermal resistance of attic insulation. If attic bypasses are not properly sealed, increasing attic ventilation may increase the home’s air-leakage rate.

✔ Install an attic access hatch if none is present. This attic hatch should be at least 22 inches square if possible.

**Insulated attic hatch:** Foam insulation prevents this area from being a thermal weakness. Use weather strip, not caulk, to seal around the hatch door.

✔ Build an insulation dam around the attic access hatch. Build the dam with rigid materials like plywood or oriented-strand board so that it will support the weight of a person entering or leaving the attic. Install latches, sash...
locks, gate hooks or other positive closure to provide substantially airtight hatch closure where appropriate.

**Title.2.3 Attic venting**

Attic ventilation is intended to remove moisture from the attic during the heating season and to remove solar heat from the attic during the cooling season.

Where possible, attics should be ventilated to a minimum ratio of one square foot of free vent area to 300 square feet of attic area.

Preventing moisture from entering the attic is now recognized as a best practice, superior in results to attic-venting for keeping attic insulation dry. Ceilings should be thoroughly air-sealed to prevent leakage of moist indoor air through the ceiling, which deposits condensation in the insulation during cold weather.

Attic venting can increase ceiling air leakage by increasing the stack effect. Attic decking, cooled by heat radiation into the cold night sky, can condense water out of ventilating air in some climates.

**Low and high attic or cross ventilation:** Ventilation creates air exchange with outdoors to evaporate condensation or roof leakage and to keep the attic from overheating in summer.
Title 2.4 Blowing attic insulation

Attic insulation should be installed to a cost effective R-value as determined by the existing insulation and climatic region. Insulation should be installed to a uniform depth according to manufacturers’ specifications for proper coverage (bags per square foot ratio) to attain the desired R-value at settled density. Attic insulation always settles. Cellulose settles 10% to 20% and fiberglass settles 3% to 10%.

Blown insulation is preferred to batt insulation because blown insulation forms a seamless blanket. Blowing attic insulation at the highest achievable insulation density helps minimize settling and prevents convection currents from moving within the insulation.

The highest density is achieved by moving the least amount of insulation through the hose with the highest available air pressure. The more the insulation is packed together in the blowing hose, the greater its installed density will be. Install per manufacturer’s specifications.

Blown-in attic insulation: Blown insulation is more continuous than batts and produces better coverage. Insulation should be blown at a high density to reduce settling.

Title 2.5 Installing batt insulation

If batt insulation must be used in the attic, then it must be installed in such a manner to ensure tight fit between ceiling joists. Unfaced fiberglass insulation is preferred to faced insulation because the facing is a hindrance to the insulation laying flat. If the insulation has vapor barrier facing, it should be
toward the heated space. If additional batt insulation is to be installed on top of existing insulation is must be unfaced to allow drying of the insulation should it get wet.

**Title.2.6 Finished attics of 1 1/2-story homes**

The finished attic consists of five separate sections that may require different sealing and insulating methods.

1. Exterior finished attic walls (end walls of finished attic).  
   *See "Wall insulation" on page 187.*

2. Collar-beam attic (above finished attic).

3. Sloped roof (where wall/roof finish is installed directly to roof rafters).

4. Knee walls (between finished attic and unconditioned attic space).

5. Outer ceiling joists (between knee wall and top plate of exterior wall).

Follow these specifications when insulating finished attics. See also “Sealing bypasses” on page 163.

- Seal attic bypasses before insulating.
- Assure adequate structural integrity to support the weight of the insulation.
- Create an airtight and structurally strong seal in the joist space under the knee-wall.
- Cut 2-inch-thick foam sheets an inch short in length and width and foam their perimeters with one-part foam. Insert a fiberglass batt to block the empty space and foam the opening and its perimeter with two-part spray foam. See “Respiratory health” on page 81 for safety precautions for using foam.
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Where possible, insulate sloped roof with dense pack cellulose.

Insulate knee walls with densely packed cellulose or fiberglass. Prepare the knee wall for blowing by nailing house wrap to the knee wall with large-headed nails or stapling the house wrap through a strip of cardboard or thin wood. Or insulate the knee wall with high-density batts and apply house wrap to the attic side of the wall to prevent convection and air leakage.

When knee-wall area is used for storage, cover insulation with a vapor-permeable material such as house wrap to prevent exposure to insulation fibers.

Insulate knee-wall access hatches and collar-beam access hatch to the same R-value as the surrounding required R-value. Weatherstrip and provide positive closure (latch, sash locks, gate hooks, etc.) to hatches where appropriate.

Finished attic: This illustration depicts two approaches to insulating a finished attic. Either insulate the kneewall and side attic or insulate the rafters.
**Title.2.7 Walk-up stairway and door**

Think carefully about how to establish a continuous insulation and air barrier around or over the top of an attic stairway. If the attic is accessed by a stairwell and standard vertical door, blow dense-packed cellulose insulation into walls of the stairwell. Install a threshold or door sweep, and weatherstrip the door. Also blow packed cellulose insulation into the cavity beneath the stair treads and risers.

When planning to insulate walls and stairway, investigate barriers that might prevent insulation from filling cavities you want to fill and what passageways may lead to filling other areas (like closets) by mistake. Balloon-framed walls and deep stair cavities complicate this measure and may prevent blown insulation from being cost-effective.
Retractable attic stairways are sometimes installed above the access hatch. Building an insulated box or buying a manufactured stair-and-hatchway cover are good solutions to insulating and sealing this weak point in the thermal boundary.

**Insulating and sealing a retractable attic stairway**

Manufactured retractable-stair cover: Magnetic tape forms the seal of this manufactured insulated cover made of molded polystyrene foam.
Title 2.8 Air sealing and insulating row house attics

This section describes methods on how to effectively air seal and insulate flat roof attics in older brick row houses common to Southeastern Pennsylvania. Although attic insulation may seem to be a very straightforward energy saving measure, research has shown that the “standard” approach applied to shallow roof cavities often provides lower energy savings than expected.

Air leakage from the house into the attic and out through the vents is the primary reason for this disappointing performance. The air moves up through passages formed by many construction features common to brick row houses such as furring strip spaces on exterior walls, duct chases, chimneys and plumbing stacks. These leakage paths allow warm house air to go through or around the insulation.

Row house stack effect: Standard methods for installing attic insulation are not very effective because of the many opportunities for air leakage throughout the building’s structure.
A new approach to insulating these attics, which focuses on sealing the bypasses, was developed and field tested. This approach involves crawling through the small attic space and directly sealing as many bypasses as feasible with rigid barriers, foam sealant and caulk, combined with blowing cellulose at high densities up to the roof deck to seal bypasses in inaccessible areas in the rear of the attic. Research found that bypasses must be sealed from the attic, not from inside the house, because there are just too many openings into bypasses once they are inside walls, chases, and the floor system. Research also found that attic ventilation in these houses can increase heat loss and condensation if bypasses are left unsealed.

**Row house attic construction features**

The figure below shows the construction of a flat roof attic for a typical Philadelphia row house. The attic is about two to three feet high at the front wall. The roof slopes downward to the rear at the rate of about 1 in 25, usually leaving less than a foot of clearance at the rear wall. The roof is sheathed with thick rough-sawn boards supported by large rafters, which are pocketed into the brick party walls between houses. The ceiling joists run from front to rear and are supported by interior partition walls and stringers from the rafters.

*Row house attics:* Utilize unique construction methods that make insulating the attic challenging.

Ceilings are plaster on wood lath. The exterior walls of the house are two courses of brick with an interior finish of plaster on wood lath, which is attached to furring strips on the walls. The spaces between the furring strips are usually open from
basement to attic. Most partition walls have top plates, but many do not. Virtually every house has a chimney and a plumbing stack, which run from the basement up through the attic and roof.

**Attic insulation & air sealing approach**

The general approach for effectively insulating and sealing bypasses involves four steps:

**Set-up**

- Inspect the roof for potential leaks. Any problems should be fixed before insulating otherwise the insulation may get wet and lose effectiveness.
- Note locations of bypasses such as duct chases and closets, and look for roof leaks or weak ceilings.
- Check over suspended ceilings since they often hide damaged plaster above.
- Knob and Tube wired ceiling light fixtures or unprotected junctions may not be covered with insulation. Consider replacing Knob and Tube wiring
- Bring all needed tools and materials onto the roof.
- Cut an access hole in the roof about 10 feet back from the front wall. It should be big enough for a person to fit through and small enough to be covered.

**Seal bypasses**

- Enter the roof cavity, bringing all needed air sealing materials and tools and the insulation hose, making sure to distribute weight on the ceiling joists and not on the plaster.
- Crawl as far to the rear as possible and directly seal all accessible rear bypasses.
- Dense pack the rear wall perimeter and the tops of any inaccessible rear chases with cellulose at 3.5 lbs. per cubic foot density. The entire unreachable rear section should be filled to the roof deck with insulation.
- Crawl to and seal all accessible bypasses in the rest of the attic working from the rear toward the front. At the same time, another crawler can go to the front and directly seal bypasses there.

**Insulate**

After directly air sealing an area, blow insulation to the required depth. Be sure to allow for settling.

**Vent roof**

Vent roof as required by prevailing code.

*NOTE*: Venting a previously un-vented roof without proper attic air sealing will most likely increase the air leakage rate of the house.
Research in Philadelphia found that when bypasses aren’t sealed, adding vents can negate much of the energy savings from the insulation because of the increased bypass air leakage caused by the vent openings. The vents tend to bring house air through the attic bringing moisture with it.

**Special air sealing features**

Row houses have many types of major air leakage sites in common with other types of older housing stock. Examples include pocket doors, open topped partition walls, dropped ceilings, chimneys etc. There are some unique construction features about row houses and specific air sealing strategies that are worth mentioning here.

**Furring strip channels**

Exterior walls were built with vertical furring strips fastened to the brick and then the lath and plaster attached to the furring strips. The furring strips provide a break between potentially moist bricks and the interior plaster. Unfortunately, they also create an open channel from basement to attic about a half inch wide on all exterior walls. This channel allows air to leak from the basement and all penetrations in the wall (baseboards, electric outlets, etc.) directly up into the attic.

Foam the tops of the channels between the furring strips. If the gap is very wide, insulation can be stuffed in the top and then foamed over.

**Finish up:** Vent roof as required by prevailing code. Turbine vents are not allowed.
Duct chase

A duct chase is a framed cavity, which contains a duct run from the basement to the second or third floor of the house and is usually open at the top to the attic. Duct chases are the most important bypasses to seal because they are usually very large and contain heating ducts which increase their heat loss.

Many row houses have duct chases that terminate in the attic. In three-bedroom row houses there are usually two to four duct chases. Larger chases are about one to three square feet and are often located right next to other bypasses such as the chimney chase in the front bedroom and beside the closets in the other two bedrooms. This layout lets you seal two bypasses at once. In bathrooms and some bedrooms, the chase may be inside a partition wall and therefore much smaller.

From the attic cap the chase with rigid board, fasten securely with heavy duty staples and seal with durable caulk or foam. If a wall of the duct chase is made of brick then thicker rigid board works better for making a tight friction-fit seal against the bricks.

**NOTE:** Avoid filling duct chases with loose fill insulation because a separated duct may let insulation fibers blow into living areas.

Skylights

There are two main types of skylights found in row houses: those with a framed well up through the roof deck and those flush with the ceiling which have separate ceiling and roof glazings without a well.
Row houses, which have the bathroom next to the front bedroom have a skylight with a well in the bathroom because there are no outside walls for a window to provide ventilation. In houses with this layout, the bathroom usually contains the chimney chase, plumbing stack, and sometimes a closet. The framed skylight well is leaky to the attic and is often made of vertical tongue-and-groove boards.

Some houses have skylights in the hallway, which are flush with the ceiling and have no enclosed well through the roof space. In this situation, there is another skylight in the roof deck positioned above the one in the ceiling.

For skylight wells, the well should be sealed from the attic with caulk. The entire well should be insulated up to the roof deck with fiberglass batts (blown insulation can be used, but will usually require a lot of material to reach the roof). In addition to sealing these leaks and insulating the perimeter of the well, it is a good energy saving investment to make an interior storm panel to fit over the bottom of the well at ceiling level. This panel can be made of acrylic and fastened with turn-clips, velcro, or magnetic strips.

For skylights flush with the ceiling, sometimes called lay-lights, the preferred treatment is to build an insulated well from the ceiling to the roof. If this approach is considered too expensive and the homeowner wants to keep the skylight, then the lay-light should be well sealed, additional glazing panels placed over the glass, and a tall lip built up around the lay-light in the attic to stop insulation from covering it up.

**Title.2.9 Wall insulation**

Densely packed cellulose wall insulation reduces air leakage through cracks inside walls and other closed building cavities because the fibers are driven into the cracks by the blowing machine. Where possible, insulate at a density of 3.5 lbs./cu.ft.
Install wall insulation with a uniform coverage and density. Wall cavities are like chimneys, and convection currents or air leakage can significantly reduce the insulation’s thermal performance.

If you find the existing walls uninsulated or partially insulated, add insulation to provide complete coverage for all the home’s exterior walls.

Two methods for installing sidewall insulation are commonly used in Pennsylvania: dense-pack method (one-hole) or the two-hole method. The dense-pack method is preferred because it ensures that wall achieves an adequate coverage and density of insulation.

**Inspecting walls**

- Inspect walls for evidence of moisture damage. If condition of the siding, sheathing, or interior wall finish indicates an existing moisture problem, no sidewall insulation should be installed until the moisture problem has been identified and corrected.
- Seal gaps in external window trim and other areas that may admit rain water into the wall.
✓ Inspect indoor surfaces of exterior walls to assure that they are strong enough to withstand the force of insulation blowing.

✓ Inspect for interior openings from which insulation may escape, such as pocket doors, balloon framing, un-backed cabinets, interior soffits, and closets. Seal openings as necessary to prevent insulation from escaping.

✓ Ensure that exterior wall cavities used as return ducts are not filled with insulation.

✓ Ensure that electrical circuits contained within walls aren’t overloaded. Maximum ampacity for 14 gauge copper wire is 15 amps and for 12 gauge copper wire is 20 amps. Install S-type fuses where appropriate to prevent circuit overloading.

Removing siding and drilling

Avoid drilling through siding. Where possible, carefully remove siding and drill through sheathing. This avoids the potential lead-paint hazard of drilling the siding. It also makes it easier to insert flexible fill tubes since the holes pass through one less layer of material.

If the siding cannot be removed, consider drilling the walls from inside the home. Obtain the owners permission before doing so, and practice lead-safe weatherization procedures. See “Lead-safe weatherization” on page 76.

✓ Asbestos shingles may be carefully removed by pulling the nails holding them to the sheathing or else nipping off the nailheads. The shingles are brittle and break easily. Dampening the asbestos tiles keeps dust down. Wear a respirator when handling asbestos shingles.

✓ Metal or vinyl siding may be removed with the aid of a zip tool.

✓ Homes with brick veneer or blind-nailed asbestos siding may be insulated from the inside. Holes drilled for insula-
tion must be returned to an appearance as close to original as possible or satisfactory to the customer.

✓ Probe all wall cavities through holes, as you drill them, to identify fire blocking, diagonal bracing, and other obstacles.

✓ After probing, drill whatever additional holes are necessary to ensure complete coverage.

Removing asbestos shingles: End-cutting nippers are employed to pull the two face nails out of each shingle. Holes are then drilled in the sheathing for tube filling.

Zip tool: A zip tool separates the joint in metal siding.
Dense-packing wall insulation

1. Drill 2-to-3-inch diameter holes to access stud cavity.

2. To prevent settling, cellulose insulation must be blown at 3.5 pounds per cubic foot density. This minimum density translates into 1.2 pounds per square foot in a 2-by-4 wall cavity on 16-inch centers, and 1.8 pounds per square foot in a 2-by-6 wall cavity on 16-inch centers. Blowing cellulose insulation this densely typically requires using a fill-tube.

3. Dense-packed wall insulation is best installed using a blower equipped with separate controls for air and material feed.

4. Marking the fill-tube in one-foot intervals allows the person blowing insulation to verify the correct penetration of the tube into the wall.

5. Starting with several full-height, unobstructed wall cavities allows the crew to measure the insulation density. Start with an empty hopper. Fill the hopper with a bag you’ve weighed. An 8-foot cavity should consume a minimum of 10 pounds of cellulose insulation.

Tube-filling walls: This method can be accomplished from inside or outside the home. It is the preferred wall-insulation method because it is a reliable way to achieve a uniform coverage and density.
6. Seal and plug holes before replacing siding.

With balloon-framed walls, try to blow an insulation plug in each floor cavity to insulate the perimeter between the two floors. This also seals the floor cavity so it does not become a conduit for air migration. If the process is requiring too much insulation, try placing a plastic bag over the end of the fill tube and blowing the insulation into the plastic bag. The bag will limit the amount of insulation it takes to plug this area.

Two-hole method

The two-hole method is often used when the insulator doesn’t want to remove siding. The two-hole method is not a preferred wall-insulation method because voids and sub-standard density are common. When using this method, employ a powerful blowing machine, preferably one with a gasoline engine.
Drill two holes into each stud cavity large enough to admit a directional nozzle. The top hole should be located no more than 20 inches below the top plate. The bottom hole should be no more than 24 inches above the bottom plate.

Probe wall cavities to determine location of obstacles and nature of cavities around window and door areas.

All wall cavities around windows and doors should be filled with insulation.

Seal all holes with wood or plastic plugs.

Open-cavity wall insulation

Fiberglass batts are the most common open-cavity wall insulation. They achieve their rated R-value only when installed carefully. If there are gaps between the cavity and batt at the top and bottom, the R-value can be reduced by as much as 30 percent. The batt should fill the entire cavity without spaces in corners or edges.

Use unfaced friction-fit batt insulation where possible. Fluff to fill entire wall cavity.

Choose R-13 batts rather than R-11.

Fiberglass batts, compressed by a cable: This reduces the wall’s R-value by creating a void between the wire and interior wallboard.

Batt, split around a cable: The void is avoided, and the batt achieves its rated R-value.
✓ Staple faced insulation to outside face of studs; avoid inset stapling.

✓ Cut batt insulation to the exact length of the cavity. A too-short batt creates air spaces above and beneath the batt, allowing convection. A too-long batt will bunch up, creating air pockets.

✓ Split batt around wiring, rather than letting the wiring bunch the batt to one side of the cavity.

✓ Insulate behind and around obstacles with scrap pieces of batt before installing batt.

✓ Fiberglass insulation exposed to the interior living space must be covered with minimum 1/2-inch drywall or other material that has an ASTM flame spread rating of 25 or less.

**Title.2.10 Floor insulation**

Floor insulation is undertaken in conjunction with air-sealing to complete the thermal boundary at the base of the building. To establish an effective thermal boundary, the insulation and air barrier should be adjacent to each other and continuous. Establishing an effective air barrier—comparable to the air barriers in the above-grade walls and ceiling—may be difficult. Furthermore, floor insulation may or may not be cost-effective or practical, considering the home’s weatherization budget and potential moisture problems.

With floor insulation, install a ground air/moisture barrier in crawl spaces and dirt-floor basements. Use six-mil plastic or cross laminated polyethylene. Any ducts from exhaust fans or clothes dryers that terminate in crawl spaces or basements should be extended to the outside.

**Rim insulation and air-sealing**

The joist spaces at the perimeter of the floor are a major weak point in the air barrier and insulation. Insulating and air-sealing
both the rim joist and longitudinal box joist are appropriate either as individual procedures or as part of floor or foundation insulation.

Air-seal stud cavities in balloon framed-homes as a part of insulating the rim joist. Air-seal other penetrations through the rim before insulating. Two-part spray foam is the most versatile air-sealing and insulation system for the rim-joist because spray foam air-seals and insulates in one step. Polystyrene or polyurethane rigid-board insulation is also good for insulating and air-sealing the rim-joist area. Longitudinal box joist cavities, enclosed by a floor joist, may be sealed and blown with wall insulation unless moisture is present.

Fiberglass-batt insulation should not be used because air can circulate around the fiberglass causing condensation and encouraging mold on the cold rim joist. If foam boards are used to insulate the rim, liquid foam sealant should be used to seal around the foam board.

**Foam-insulated rim joists:** Installing foam insulation is the best way to insulate and air-seal the rim joist. The R-value of the foam should be between 11 - 14, depending on the foam.

**Floor insulation**

All appropriate measures should be taken to establish an effective air barrier at the floor, prior to insulating the floor, to prevent air from passing through or around floor insulation. The
best way to insulate a floor cavity is to completely fill the joist cavity with unfaced fiberglass-batt insulation. Partially filling the cavity with a fiberglass batt is less satisfactory because securing the batts up against the subfloor can be difficult. Consider the following specifications.

- Install R-19 insulation between floor joists.
- Install insulation without voids, edge gaps, or end gaps.
- Fit insulation closely around cross bracing and other obstructions.

**Floor insulating with batts:** Use unfaced fiberglass batts, installed flush to the floor bottom, to insulate floors. The batt should fill the whole cavity if it is supported by lath or plastic twine underneath. For batts that don’t fill the whole cavity, use wire insulation supports.

- Securely fasten batt insulation to framing with insulation hangers, plastic mesh, or other supporting material.
- Fit floor insulation tightly against the subfloor and the rim joist to prevent convecting air above the insulation from reducing its R-value.
- If the walls are balloon framed, air seal stud cavities prior to installing floor insulation.
- Insulate water lines if they protrude below the insulation.
✔ Seal and insulate ducts remaining in the crawl space or unoccupied basement.

✔ In crawl spaces, install a ground moisture barrier that runs up the foundation walls.

Ground moisture and air barriers

The ground is neither an air barrier nor a moisture barrier and can transport air and moisture into a crawl space. Crawl-space moisture can lead to condensation, mold, and rot. Air passing through the soil can also contain radon and pesticides. Covering the ground with an airtight moisture barrier establishes an air barrier and seals out moisture and soil gases.

Best practice involves sealing the seams in the ground moisture barrier with construction tape or acoustical sealant, making it both an air barrier and a moisture barrier. If the crawl-space access is difficult or if the air barrier is at the floor, the polyethylene need not be sealed.

Crawl space ventilation

Crawl-space ventilation is generally not required if:

- There are no signs of standing water,
- The crawl space is dry,
- There is proper surface drainage, and
- There is a properly installed ground air-moisture barrier.

If the above conditions can’t be met, install one square foot of net free ventilation area for every 1500 square feet of crawl-space floor area. A minimum of two vents must be installed and should be located on opposite sides of the crawl space.
An air barrier, aligned with the insulation, forms the building’s thermal boundary. The home may or may not have an effective air barrier surrounding it. The testing described here will help you analyze the existing air barriers and decide whether and where air-sealing is needed. The energy impact of duct leakage depends on whether the ducts are located within or outside of the thermal boundary.

Controlling shell air leakage is the key ingredient in a successful weatherization job. Air leakage influences every aspect of weatherization. The decisions you make about sealing air leaks will affect a building dramatically throughout its lifetime. Consider the following major effects of air leakage.

- Air leakage creates up to 40% of a building’s heat loss.
- Air leakage can significantly reduce insulation R-value.
- Air leakage moves moisture into and out of the house, and exerts a wetting and/or drying effect.
- The type and amount of air leakage can determine whether or not a combustion appliance like a furnace or fireplace will vent its gases out the chimney as it should.

Furthermore, air leakage usually provides ventilation for exhausting pollutants and admitting fresh air. However, air leaks can bring pollutants in as easily as they let pollutants out.

Air-sealing or duct sealing may affect combustion-appliance venting by increasing house pressures or reducing the available supply of combustion air. After all weatherization materials have been installed, all crews or contractors should conduct worst-case draft testing and check the safety of all combustion appliances as described in “CAZ Combustion Safety Test” on page 103.
The first goal of air-leakage and pressure testing is to decide how much time and effort is required to achieve acceptable air-leakage and duct-leakage rates, while safeguarding indoor air quality. For more on indoor air quality, see “Client health and safety” on page 63.

The second goal of leak-testing is to decide where to locate the air barrier when an intermediate zone like an attic or crawl space presents two choices of air barriers. The ceiling is usually the thermal boundary, rather than the roof. However, at the foundation, the air barrier can be located at the first floor or at the foundation wall.

Duct leakage in the heating system is now established as one of the major treatable energy problems in homes. However, sealing every joint without testing can be a waste of time and money. Duct leakage tests help you determine the severity and locations of duct leaks.

The reason for the number of air-leakage and duct-leakage tests is that there is so much uncertainty about air leakage and duct leakage. Air leakage and duct leakage are a problem in many homes but not in others. Testing is needed because there simply is no accurate prescriptive method for determining the severity and location of leaks. Depending on the complexity of a home,
you may need more or less testing to control air leakage and duct leakage to within accepted standards.

**Title.1 House Airtightness Testing**

House airtightness testing was made possible by the development of the blower door, shown here. The blower door measures a home’s leakage rate at the standard pressure of 50 pascals. This leakage measurement can be used to compare homes with one another and to set air-leakage standards.

**Blower door components:** Include the frame, panel, fan, and manometer.

The blower door also allows the technician to test parts of the home’s air barrier to locate air leaks. Sometimes air leaks are obvious. More often, the leaks are hidden, and the technician wants to obtain clues about their location. This section outlines the basics of blower door measurement along with some techniques for gathering clues about the location of air leaks.

**Title 2 Blower-Door Testing**

The blower door creates a 50-pascal pressure difference across the building shell and measures airflow in cubic feet per minute at 50 Pascals (CFM$_{50}$), in order to compare the leakiness of homes. PAWAP requires that dwelling units shall have a blower door test performed both before and after building shell weatherization retrofit. It’s purpose is to help locate air leakage and to monitor the level of air tightening resulting from sealing and insulating the building shell.

The minimum blower door generated value to be obtained and documented in the client file is air flow in cubic feet of air per minute at a house pressure difference of 50 pascals (CFM$_{50}$).

A one point reading at 50 pascals is the minimum requirement for estimating CFM$_{50}$. A one point test is achieved by the interpretation of one data set, which includes one house and one fan pressure reading from the manometer.

Technicians may perform as many blower door tests as they wish to monitor the progress of their air sealing work. This is encouraged. However, a minimum of one “Pre Test” and one “Post Test” must be documented in the client file.
The blower door also creates pressure differences between rooms in the house and intermediate zones like attics and crawl spaces that can give clues about the location and size of a home’s air leaks. For more information on air-leak location, see “Sealing bypasses” on page 163.

Title.2.1 Measuring pressure and airflow

Connecting the manometer’s hoses correctly is essential for accurate testing. A widely accepted method for communicating correct hose connection helps avoid confusion. This method uses the phrase “with reference to”, “WRT”, to discriminate between the input zone and reference zone for a particular measurement. The outdoors is the most commonly used reference zone for blower door testing. The reference zone is considered to be the zero point on the pressure scale. For example, house WRT outdoors = –50 pascals means that the house (input) is 50 pascals negative compared to the outdoors (reference or zero-point). The pressure reading in the last example is called the house-to-outdoors pressure difference.

During the blower door test, the airflow is measured through the fan. This airflow is directly proportional to the surface area...
of the home’s air leaks. For the blower door to measure airflow accurately, the air must be flowing at an adequate speed. Tighter buildings don’t have enough air leakage to create an adequate airspeed. This necessitates using one of three low-flow plates provided with the blower door to reduce the fan’s opening and increase air speed through the fan.

When using one of these low-flow plates, you must read the correct scale on the analog gauges, shown below. When using a digital gauge, follow the manufacturer’s instructions for selecting the proper fan configuration corresponding to the correct low-flow plate.

Some homes are so leaky that the blower door isn’t powerful enough to depressurize them to –50 pascals. In these cases, you must apply a factor to the airflow you measure at a lower pressure. Those factors are listed in Table Title-1 on page 208. Use these factors only when absolutely necessary because they may result in inaccurate air leakage estimates.
Title 2.2 Preparing for a blower door test

Preparing the house for a blower door test involves putting the house in its heating operating condition with all conditioned zones open to the blower door. Try to anticipate safety problems that the blower door test could cause, particularly with combustion appliances.

- Identify the location of the thermal boundary and determine which house zones are conditioned.
- Identify large air leaks that could prevent the blower door from achieving adequate house pressure.
- Survey pollutant sources that may pollute the air during a blower door test — wood stove or fireplace ashes for example.
- Put the house in its heating mode with windows and doors closed and air registers open.
- Turn off combustion appliances temporarily.
- Open interior doors so that all indoor areas inside the thermal boundary are connected to the blower door. This could include the basement, conditioned kneewall areas, and closets. Don’t open access doors between the home and its intermediate zones, which are outside the thermal boundary, such as attics, crawl spaces, and attached garages.
- Calculate house volume if you plan to use \(\text{ACH}_{50}\) (air changes per hour at 50 pascals) or \(\text{ACH}_{n}\) (air changes per hour – natural). Calculate volume by multiplying length by width and then by height to arrive at the number of cubic feet of volume.

Adjusting for Baseline Pressure

To obtain accurate blower door measurements, you must correct your target house pressure reading on the digital manometer to adjust for wind and stack effect. The most common digital manometers have a “Baseline” function that automatically can-
cels the measurement effect of wind or stack pressures. Follow the manufacturer’s instructions about how to adjust the baseline pressure.

Adjust the measured pressure of older or simpler digital manometers by adding or subtracting pressure from the target blower door pressure of 50 pascals. A positive house pressure without blower door operation reduces the target blower door negative house pressure. A negative house pressure would increase the negative target blower door house pressure.

Block the blower door’s opening to prevent ambient airflow through the fan before measuring the baseline pressure. Make sure that the house-pressure hose is connected to outdoors and that the fan hose is connected. Measure the baseline house pressure with the blower door off.

If you read a positive house pressure of three pascals with reference to outdoors, add those pascals to -50 pascals and set the house pressure at -47 pascals to get your accurate airflow (CFM<sub>50</sub>). If you read a negative house pressure of 2 pascals subtract those pascals from -50 pascals, and then set the blower door to produce -52 pascals to get your accurate airflow.

**Title.2.3 Blower Door Test Procedures**

Follow this general procedure when performing a blower door test.
• Set up the house for winter conditions with exterior doors, primary windows and storms closed. The door to the basement should be either open or closed according to whether or not the basement is considered to be inside the thermal boundary.

• Install blower door frame, panel, and fan in an exterior doorway with a clear path to outdoors. On windy days, try not to place the fan opposing the wind direction.

• Follow manufacturer’s instructions for fan orientation and digital-manometer setup for either pressurization or depressurization.

• Connect Channel A of the digital manometer to measure house WRT outdoors. Place the outside hose at least 5 feet to the side of the fan and against the foundation.

• Connect Channel B to measure fan WRT zone near fan inlet. The zone near the fan inlet is indoors for depressurization and outdoors for pressurization. (Hose must run from the reference port on channel B to outdoors for pressurization.)

• Adjust for the stack or baseline reading, previously referenced in “Adjusting for Baseline Pressure” on page 205. If the manometers used do not zero automatically or manually, the house pressure must be adjusted for this baseline reading (house WRT outdoors).

• Ensure that people, pets, and objects with the potential to become airborne remain at a safe distance from the fan.

• Turn on the fan and increase its speed slowly until you read -50 pascals of pressure difference between indoors and outdoors.

• Read the CFM_{50} from channel B of your digital manometer.
Digital Manometer Set-Up Procedures

Follow these instructions for performing a blower door test, using a digital manometer.

- Turn on the manometer by pushing the ON/OFF button
- Use the MODE function to select the displayed results, such as airflow in CFM at 50 pascals for example.
- Use the DEVICE function to select to select a particular blower door model.
- Use the BASELINE function to adjust for the baseline pressure.
- Select the correct configuration for an open fan or one of the flow rings or range plates.
  a. Install the flow ring or range plate in the blower door fan, which produces an adequate airflow rate. The fan pressure should be at least 25 pascals.
  b. Use CONFIG (configuration) function until you match the flow ring or range plate being used.
- Turn on the blower door fan slowly with the controller. Increase fan speed until the building depressurization on the Channel A screen is between -45 and -55 Pascals. It does not need to be exactly -50 Pascals unless you are using an older digital manometer.

Table Title-1: ‘Can’t Reach Fifty’ Factors

<table>
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<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
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<td>1.6</td>
<td>1.4</td>
<td>1.3</td>
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</table>

Thanks to The Energy Conservatory

Note: See sections 1.1.3 and 1.1.4 of the Pennsylvania Weatherization Field Standards if this is confusing to you.
• The screen displays the CFM$_{50}$ leakage of the building. If this number is fluctuating a lot, select the TIME AVERAGE function to increase the time-averaging duration. Increasing the time-averaging duration dampens the wind’s effect on the reading.

**Blower Door Test Follow-Up**

Be sure to return the house to its original condition after completing the blower door test.

• Inspect combustion appliance pilot lights to ensure that blower door testing did not extinguish them.

• Reset thermostats of heaters and water heaters that were turned down for testing.

• Remove any temporary plugs that were installed to increase house pressure.

✓ Document any unusual conditions affecting the blower door test and location where the blower door was installed.
### Table Title-2: Fan Pressure and Airflow for MN Blower Door Model

<table>
<thead>
<tr>
<th>Fan Pressure</th>
<th>Open fan</th>
<th>Ring A</th>
<th>Ring B</th>
<th>Fan Pressure</th>
<th>Open fan</th>
<th>Ring A</th>
<th>Ring B</th>
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Title.2.4 Building Airflow Standard (BAS)

Air leakage must provide fresh outdoor air when no mechanical ventilation system exists because the air leaks are the home’s only means of fresh air intake and pollutant removal. Follow the current ASHAE Standard to determine the building airflow standard (BAS).

Indoor Air Quality

Indoor air quality and ventilation also may be priorities for homes testing below the BAS. The importance of air quality control and ventilation depend on answers to the following questions.

- Are sources of moisture like ground water, humidifier, water leaks, unvented clothes dryer, or unvented space heater causing indoor air pollution, high relative humidity, or moisture damage? See “Solutions to moisture problems” on page 74.
- Do occupants complain or show symptoms of building-related illnesses?

Pollutant sources combined with tight houses produce poor indoor air quality. Educate residents about removing pollution sources and ventilating their homes. Take appropriate steps during weatherization to reduce pollutants and to install mechanical ventilation if needed. See “Mechanical ventilation” on page 75 for more information.

Title.3 Zonal Pressure Diagnostics

Leaks in air barriers cause energy and moisture problems in many homes. You can test air barriers for leakiness during blower-door testing. Zonal pressure diagnostics avoids unnecessary visual inspection and air-sealing in hard-to-reach areas. Zonal pressure diagnostics use a manometer to measure pres-
sure differences between zones in order to estimate air leakage between zones. Specifically air-barrier leak-testing can:

- Evaluate the airtightness of portions of a building’s air barrier—especially floors and ceilings.
- Decide which of two possible air barriers to air seal—for example, the floor versus foundation walls.
- Estimate the air leakage in CFM$_{50}$ through a particular air barrier, for the purpose of estimating the effort and cost necessary to seal the leaks.

\[ \text{cfm} = 1.07 \times \text{area} \times \sqrt{\Delta p} \]

**Blower door test:** Zonal pressure diagnostics involves a series of techniques, applied during a blower-door test, with the house at a negative pressure of 50 pascals with reference to outdoors. If CFM50 cannot be achieved, go to the next lowest even number using half of that as the relative connection determining point. This house has 3000 CFM50 of air leakage. Testing air barriers can help determine where that leakage is coming from.

- Determine whether building cavities like floor cavities, porch roofs, and overhangs are conduits for air leakage.
- Determine whether building cavities, intermediate zones, and ducts are connected by air leaks.

Zonal pressure diagnostics provides a range of information from simple clues about which parts of a building are leakiest, to spe-
cific estimates of the airflow and hole size through a particular air barrier like a ceiling.

When you’re planning to identify and improve a home’s air barrier, consider the leakage characteristics of the building components. Creating an effective air barrier in an existing home involves choosing existing building components to act as air barriers and then air-sealing their border regions. Chances are that you’ll find two or more of these components adjacent to one another so that they combine to form a better air barrier compared to being considered alone. The classification below includes only the component itself, not seams and border areas where it meets other components.

**Title.3.1 Primary versus secondary air barriers**

The air barrier should be a material that is continuous, sealed at seams, and is itself relatively impermeable to airflow. Where there are two possible air barriers, the most airtight air barrier is the primary air barrier and the least airtight is the secondary air barrier. The primary air barrier should be adjacent to the insulation to ensure the insulation’s effectiveness. Therefore, testing is important to verify that insulation and primary air barrier are together. Sometimes we’re surprised during testing to find that our assumed primary air barrier is actually secondary, and the secondary air barrier is actually primary. For example, the roof may be the primary air barrier instead of the top-floor ceiling as assumed.

Intermediate zones are unconditioned spaces, sheltered within the exterior shell of the house. Intermediate zones can be included inside the home’s primary air barrier or outside it. Intermediate zones include: unheated basements, crawl spaces, attics, enclosed porches, and attached garages. Intermediate zones have two potential air barriers: one between the zone and house and one between the zone and outdoors. For example, an attic or roof space has two air barriers: the ceiling and roof.
Title 3.2  Very simple pressure tests

You can find valuable information about the relative leakiness of rooms or sections of the home during a blower-door test. Listed below are 4 simple methods.

1. **Feeling zone air leakage:**
   Close an interior door partially so that there is a one-inch gap between the door and door jamb. Feel the airflow along the length of that crack, and compare that airflow intensity with airflow from other rooms, using the same technique. Discovering that there is a lot of leakage coming from one zone and only a little coming from another is this test’s limit.

2. **Room pressure difference:**
   Check the pressure difference between a closed room or zone and the main body of a home. Larger pressure differences indicate larger potential air leakage within the closed room or else a tight air barrier between the room and main body. A small pressure difference means little leakage to

![Diagram](image)

**Interior door test:** Feeling airflow with your hand at the crack of an interior door gives a rough indication of the air leakage coming from the outdoors through that room.

**Bedroom test:** This bedroom pressure difference may be caused by its leaky exterior walls or tight interior walls, separating it from the main body of the home. This test can determine whether or not a confined combustion zone is connected to other rooms.
the outdoors through the room or a leaky air barrier between the house and room.

3. *Observing the ceiling/attic floor:* Depressurize the home to 50 pascals and observe the top-floor ceiling from the attic with a good flashlight. Air leaks will show in movement of loose fill insulation, blowing dust, moving cobwebs, etc.

4. *Observing smoke movement:* Depressurize the home to 50 pascals and observe the movement of smoke through the house and out of its air leaks.

Tests 1, 3, and 4 are important observations. Feeling airflow with your hand or observing smoke are mere observations and are good client education opportunities. These simple techniques have helped identify many air leaks that could otherwise have remained hidden. Closing doors to leakier rooms will usually produce a greater reduction in CFM$_{50}$ than closing doors to tighter ones.

Air leakage, restricted by closing a door, may have alternative indoor paths rendering test 2 inaccurate. Only practice and experience can guide your decisions about the applicability and usefulness of these tests.

**Title.3.3 Using a manometer to test air barriers**

A manometer pressure gauge, used for blower door testing, also can measure pressures between the house and its intermediate zones during blower door tests.

The blower door, when used to create a house-to-outdoors pressure of $-50$ pascals, also creates house-to-zone pressures of between 0 and $-50$ pascals in the home’s intermediate zones. The amount of depressurization depends on the relative leakiness of the zone’s two air barriers.
Diagnosing Shell & Duct Air Leakage

For example, in an attic with a fairly airtight ceiling and a well-ventilated roof, the attic will indicate that it is mostly outdoors by having a house-to-zone pressure of –45 to –50 pascals. The leakier the ceiling and the tighter the roof, the smaller the negative house-to-zone pressure will be. This holds true for other intermediate zones like crawl spaces, attached garages, and unheated basements.

**Title.3.4  Zonal pressure diagnostic methods**

Depressurize house to –50 pascals with a blower door.

1. Find an existing hole, or drill a hole through the floor, wall, or ceiling between the conditioned space and the intermediate zone.

2. Connect the reference port (digital manometer) or the low-pressure port (analog manometer) to a hose connected into the zone.
3. Leave the input port (digital manometer) or the high-pressure port (analog manometer) open to the indoors.

4. Read the negative pressure given by the manometer. This is the house-to-zone pressure, which will be –50 pascals if the air barrier between house and zone is air-tight and the zone is open to outdoors.

5. If the reading is significantly less negative than –45 pascals, find the air barrier’s largest leaks and seal them.

6. Repeat steps 1 through 5, performing more air-sealing as necessary, until the pressure is as close to –50 pascals as possible.

**House-to-attic pressure:** This commonly used measurement is convenient because it requires only one hose.

**Attic-to-outdoors pressure:** This measurement confirms the first because the two add up to –50

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**Leak-testing building cavities**

Building cavities like wall cavities, floor cavities between stories, and dropped soffits in kitchens and bathrooms can also be tested as described above to determine their connection to the outdoors as shown here.
Testing zone connectedness

Sometimes it is useful to determine whether two zones are connected by an air passage like a large bypass. Measuring the house-to-zone pressure during a blower door test before and then after opening the other zone to the outdoors can establish whether the two zones are connected. You can also open an interior door to one of the zones and check for pressure changes in the other.

**Porch roof test:** If the porch roof were outdoors, the manometer would read near 0 pascals. We hope that the porch roof is outdoors because it is outside the insulation. We find, however, that it is partially indoors, indicating that it may harbor significant air leaks through the thermal boundary.

**Cantilevered floor test:** We hope to find the cantilevered floor to be indoors. A reading of –50 pascals would indicate that it is completely indoors. A reading less negative than –50 pascals is measured here, indicating that the floor cavity is partially connected to outdoors.

**Zone connectedness:** The attic measures closer to outdoors after the basement window is opened, indicating that the attic and basement are connected by a large bypass.
**Title.3.5 Zone pressures, air sealing, and insulation**

Zone pressures are one of several factors used to determine where the thermal boundary should be. Where to air-seal and where to insulate are necessary retrofit decisions. When there are two choices of where to insulate and air-seal, zone pressures along with other considerations help you decide.

Including the heating ducts within the thermal boundary is often preferred because this option reduces energy waste from duct leakage. The location of ducts either within or outside the thermal boundary is an important factor in determining the cost-effectiveness of duct sealing and insulation.

If a floor is already insulated, it makes sense to establish the air barrier there. If the foundation wall is more airtight than the floor, that would be one reason to insulate the foundation wall.

For zonal pressure diagnostics, the house-to-zone pressure is often used to determine which of two air barriers is tighter, for example.

- Readings of negative 25-to-50 pascals house-to-attic pressure mean that the ceiling is tighter than the roof. If the roof is quite airtight, achieving a 50-pascal house-to-attic pressure difference may be difficult. However if the roof is well-ventilated, achieving a near-50-pascal difference should be possible.

- Readings of 0 to –25 pascals house-to-attic pressure mean that the roof is tighter than the ceiling. If the roof is well-ventilated, the ceiling has even more leak area than the roof’s vent area.

- Readings around –25 pascals house-to-attic pressure indicate that the roof and ceiling are equally airtight or leaky.

You can use the leakage characteristics you observe in one air barrier to estimate leakage through another. The area of attic or crawl-space vents is a valuable piece of information. The relative airtightness of a building component is another.
Pressure readings more negative than \(-45\) pascals indicate that the primary air barrier is adequately airtight. Less negative pressure readings indicate that bypasses should be located and sealed. See “Sealing bypasses” on page 163.

The floor, shown here, is tighter than the crawl-space foundation walls. If the crawl-space foundation walls are insulated, holes and vents in the foundation wall should be sealed until the pressure difference between the crawl space and outside is as negative you can make it—ideally more negative than \(-45\) pascals. A leaky foundation wall renders its insulation nearly worthless.

If instead, the floor above the crawl space were insulated instead of the foundation walls, the air barrier and the insulation would be aligned in the above example.

Generally, the thermal boundary (air barrier and insulation) should be between the conditioned space and attic. An exception would be insulating the roof to enclose an attic air handler and its ducts within the thermal boundary.

The thermal boundary should always be between the conditioned space and a tuck-under or attached garage, to separate the living spaces from this unconditioned and often polluted zone.
**Title.4 Duct airtightness testing**

The blower door can be used for duct-airtightness testing at the same time that it is testing house airtightness. The goal of the tests explained below is to roughly estimate duct leakage so that a decision can be made about the level of duct-sealing necessary. For information on sealing duct leaks, see “Duct air-tightness standards” on page 135.

**Title.4.1 Pressure-pan testing**

Pressure-pan tests can help identify leaky or disconnected ducts. With the house depressurized by the blower door to –25 or -50 pascals with reference to outdoors, pressure-pan readings are taken at each supply and return register. Pressure-pan testing is reliable for manufactured houses and small site-built homes where the ducts are outside the air barrier.

Basements are often considered part of the conditioned living space of a home. In this case, pressure-pan testing isn't necessary, although air-sealing the return ducts for safety is still required. If instead, the basement is accessed from the outside and rarely used, the basement may be considered outside the conditioned living space. In this case, a window or door between the basement and outdoors should be opened, and any door or hatch between conditioned spaces and basement should be closed during pressure-pan testing.

1. Install blower door and set-up house for winter conditions. Open all interior doors.

2. If the basement is conditioned living space, open the door between basement and upstairs living spaces. If
the basement is considered outside the conditioned living space, close the door between basement and upstairs living spaces and open a basement window.

3. Turn furnace off. Ensure that all grilles, registers, and dampers are fully open.

4. Temporarily seal any outside fresh-air intakes to the duct system. Seal all registers that are in unconditioned living spaces (supply registers in unconditioned basements, for example).

5. Open attics, crawl spaces, and garages as much as possible to the outside.

6. Connect hose between pressure pan and the input tap on the digital manometer. Leave the reference tap open.

7. With the blower door at –25 pascals, place the pressure pan completely over a grille or register to form a tight seal. Record the reading.

8. If a grille is too large or a supply register is difficult to access (under a kitchen cabinet, for example), seal the grille or register with masking tape. Insert a pressure probe through the masking tape and record the reading.

9. Repeat this test for each register and grille in a systematic fashion.

**Pressure-pan duct standards**

If the ducts are perfectly sealed with no leakage to the outside, no pressure difference (0.0 pascals) will be measured during a pressure-pan test. The higher the measured pressure-pan reading, the more connected the duct is to the outdoors. Readings greater than 1.0 pascal require investigation and sealing of leaks causing the reading.

Pay particular attention to registers connected to ducts that are located in areas outside the conditioned living space. These
spaces include attics, crawl spaces, garages, and unoccupied basements as described previously. Also test return registers attached to stud cavities or panned joists used as return ducts. Leaky ducts located outside the conditioned living space may show pressure-pan readings of up to 25 pascals if they have large leaks.

**Title.5 Duct-induced pressures**

An improperly balanced air-handling system can cause comfort, building-durability, and indoor-air-quality problems. Duct-induced room pressures can increase air leakage through the building shell from 1.5 to 3 times, compared to when the air handler is off.

**Title.5.1 Measuring duct-induced pressures**

The following test measures pressure differences between the main body of the house and outdoors, between each room and outdoors, and between the combustion zone and outdoors. Pressure difference greater than +4.0 pascals or more negative than –4.0 pascals should be corrected.

1. Set-up house for winter conditions. Close all windows and exterior doors. Turn-off all exhaust fans.

**Pressure pan test:** A pressure-pan reading of 2 indicates moderate duct air leakage.

**Problem register:** A pressure reading of 7 pascals indicates major air leakage near the tested register.
2. Open all interior doors, including door to basement.
3. Turn on air handler.
4. Measure the house-to-outdoors pressure difference. This test indicates dominant duct leakage as shown here.

A positive pressure indicates that the return ducts (which pull air from leaky intermediate zones) are leakier than the supply ducts. A negative pressure indicates that the supply ducts (which push air into intermediate zones through their leaks) are leakier than return ducts. A pressure at or near zero indicates equal supply and return leakage or else little duct leakage.

1. Now, close interior doors.
2. Place hose from input tap on the manometer under one of the closed interior doors. Leave reference tap connected to outdoors.
3. Read and record this pressure measurement for each room. This pressure’s magnitude indicates the degree to which the air-handler’s airflow is unbalanced between supply and return.
If pressure difference is more than ± 4.0 pascals with the air handler operating, pressure relief is necessary. To estimate the amount of pressure relief, slowly open door until pressure difference drops to between +4.0 pascals and −4.0 pascals. Estimate area of open door. This is the area required to provide pressure relief. Pressure relief may include undercutting the door or installing transfer grilles.

For information on the danger of depressurized combustion zones, see “CAZ Combustion Safety Test” on page 103. For information on reducing duct-induced room pressures, see “Duct improvements to increase airflow and improve comfort” on page 141. For information on sealing duct leaks, see “Duct air-tightness standards” on page 135.
Manufactured houses typically use more energy per square foot than site-built homes, but their consistent construction makes them more straightforward to weatherize.

**Typical Components of a Manufactured House:**
1. Steel chassis.
2. Steel outriggers and cross members.
3. Underbelly.
4. Fiberglass insulation.
5. Floor joists.
6. Heating/air conditioning duct.
7. Decking.
8. Floor covering.
9. Top plate.
10. Interior paneling.
12. Fiberglass insulation.
13. Metal siding.
15. Bowstring trusses.
16. Fiberglass insulation.
17. Vapor barrier.
18. Galvanized steel one-piece roof.
19. Metal windows.
Insulation upgrades save the most energy in manufactured houses, though sealing shell and duct air leaks presents good opportunities, too. Manufactured house heating retrofit and replacement are often cost-effective when a customer’s energy usage is high. See “PA WAP Manufactured Home, Measure Selection Priority List (MHEA)” on page 19.

**TITLE 1 MANUFACTURED HOUSE HEATING**

Manufactured house furnaces are different from conventional furnaces in the following ways:

- A great majority of manufactured houses are equipped with downflow furnaces, designed specifically for manufactured houses.
- Manufactured house combustion furnaces are sealed-combustion units that use outdoor combustion air, unlike most furnaces in site-built homes. They don’t have draft diverters or barometric draft controls.
- Manufactured house furnaces require an outdoor source of combustion air.
- Manufactured house furnaces have either a manufactured chimney that includes a passageway for combustion air or a combustion-air chute connecting the burner with the crawl space.
- Gas-fired furnaces have kits attached, containing alternative orifices, to burn either propane or gas.
- Return air is supplied to the furnace through a large opening in the furnace cabinet, rather than through ducts connected to the blower compartment.

Manufactured house furnaces have been sealed-combustion since the early 1970s. Gas furnaces are either the old atmospheric sealed-combustion type or the newer fan-assisted mid-efficiency type. Some older sealed-combustion furnaces had
Manufactured house oil furnaces are a close relative to oil furnaces in site-built homes. However, they should have a housing that fits around the burner’s air shutter and provides outdoor air directly to the burner. See “Oil-burner safety and efficiency” on page 94 and “Direct combustion air supply to oil-fired heaters” on page 131.

**Important Note:** Install only furnaces designed for manufactured houses. The installation should include the complete chimney and roof jack assembly.

**Manufactured house furnace airflow:**
Return air flows from the hallway through the furnace grille. The air is heated and distributed through the ducts.

**Manufactured house furnace combustion:**
Combustion air enters through the flue assembly on the roof and feeds the flame through a sealed passageway.
Title 1.1 Furnace maintenance and energy efficiency

Manufactured house furnaces should comply with this guidebook’s combustion safety and efficiency standards. See “Gas burner safety and efficiency testing” on page 88 and “Oil-burner safety and efficiency” on page 94.

Title 1.2 Heating appliance replacement

Manufactured house furnaces must be replaced by furnaces designed and listed for use in manufactured houses. If a heat exchanger is available to replace the existing cracked heat exchanger, consider heat-exchanger replacement as a repair priority instead of replacing the furnace.

Consider replacing the existing furnace with a sealed-combustion, downflow, condensing furnace. Manufacturers make condensing furnaces, approved for manufactured houses. In any case replacement furnaces must fall within the specifications for HUD and Pennsylvania Combustion Efficiency Standards.

Manufactured house furnaces may be replaced when any of the following 3 conditions is observed.

1. The furnace has a cracked heat exchanger.
2. Repair and retrofit exceed half of the replacement cost.
3. The furnace is not operating and not repairable.

Follow these procedures when installing new manufactured house furnaces.

✔ Install a new furnace base.

✔ Attach the furnace base firmly to the duct, and seal all seams between the base and duct with mastic and fabric tape before installing the furnace.

✔ Support the main duct underneath the furnace with additional strapping if necessary.
When replacing manufactured house furnaces, note the differences between old furnace and new, in the way each supplies itself with combustion air.

Install a new chimney that is manufactured specifically for the new furnace. Install to manufacturer's specifications.

Manufactured house furnaces have short chimneys, and their combustion process depends on a delicate balance between combustion air entering and combustion gases leaving. The furnace demands a vertical, leak-free chimney, and a properly installed chimney cap. Follow manufacturer's installation instructions exactly.

**TITLE.2 MANUFACTURED HOUSE AIR SEALING**

The locations and relative importance of air-leakage sites was a mystery before blower doors. Some manufactured houses are fairly airtight and some are incredibly leaky. It's recommended that a blower door be used to guide air-sealing work and to check Building Airflow Standard in manufactured houses.

**Title.2.1 Air-leakage locations**

The following locations have been identified by technicians using blower doors as the most serious air-leakage sites. Window and door air leakage is more of a comfort problem than a serious energy problem.

- Plumbing penetrations in floors, walls, and ceilings. Water-heater closets with exterior doors are particularly serious air-leakage problems, having large openings into the bathroom and other areas.
- Torn or missing underbelly, exposing flaws in the floor to the ventilated crawl space.
- Large gaps around furnace and water heater chimneys. A large gap around the furnace chimney jack, combined with inadequate return air, can cause the blower fan to depres-
surize the home’s attic and draw moist outdoor air into the cavity. This moist air will condense during some seasons and cause moisture damage.

- Severely deteriorated floors in water heater compartments.
- Gaps around the electrical service panel box, light fixtures, and fans.
- Joints between the halves of double-wide manufactured houses and between the main dwelling and additions.

### Table Title-1: Air Leak Locations and Typical CFM$_{50}$ Reductions

<table>
<thead>
<tr>
<th>Air Sealing Procedure</th>
<th>Typical CFM$_{50}$ Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patching large air leaks in the floor, walls and ceiling</td>
<td>200–900</td>
</tr>
<tr>
<td>Sealing floor as return-air plenum</td>
<td>300–900</td>
</tr>
<tr>
<td>Sealing leaky water-heater closet</td>
<td>200–600</td>
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<tr>
<td>Sealing leaky supply ducts</td>
<td>100–500</td>
</tr>
<tr>
<td>Installing tight interior storm windows</td>
<td>100–250</td>
</tr>
<tr>
<td>Caulking and weatherstripping</td>
<td>50–150</td>
</tr>
</tbody>
</table>

### Title.2.2 Duct-leak locations

The following locations have been identified by technicians using blower doors and duct testers as the most serious energy problems.

- Floor and ceiling cavities used as return-air plenums. These return systems should be eliminated in favor of return-air through the hall or a large grille in the furnace-closet door.
**Floor return air:** Return air registers at the floor’s perimeter bring air back to the furnace. The floor cavity serves as one big leaky return duct. When leakage is serious, the floor return system should be eliminated.

- Joints between the furnace and the main duct. The main duct may need to be cut open from underneath to access and seal these leaks between the furnace, duct connector, and main duct. With electric furnaces, you can access the duct connector by removing the bank of resistance elements. For furnaces with empty A-coil compartments, you can simply remove the access panel to access the duct connector.
- Joints between the main duct and the short duct sections joining the main duct to a floor register.
- Joints between register boots and floor.
- The poorly sealed end of the duct trunk.
- Disconnected, damaged or poorly joined crossover duct.

**Note:** When eliminating return air in the floor, take steps to remove restrictions to return airflow. For example, trim interior doors or install grilles in doors or walls.

**Manufactured house ducts:** Manufactured house ducts leak at their ends and wherever a joint occurs—especially at the joints beneath the furnace. The furnace base attaches the furnace to the duct connector. Leaks occur where the duct connector meets the main duct and where it meets the furnace. Branch ducts are rare, but easy to find, because their supply register isn’t in line with the others. Crossover ducts are found only in double-wide and triple-wide homes (A double-wide home has a single furnace; however each section has its own main duct. These main ducts are connected by the crossover duct.)
TITLE.3 MANUFACTURED HOUSE INSULATION

Over the past 15 years, effective methods for insulating manufactured houses have been developed by weatherization agencies. Use the following standards for floor and ceiling insulation.

Remove all significant moisture problems before insulating. The most important moisture-control measure is installing a ground-moisture barrier under manufactured housing that does not have existing vapor barrier under the belly. See “Gas range and oven safety” on page 66.

Title.3.1 Blowing manufactured house roof cavities

Blowing a closed manufactured house roof cavity is similar to blowing a closed wall cavity, only the insulation doesn’t have to be as dense. Fiberglass blowing wool is used since cellulose is too heavy and absorbs water too readily for use around a manufactured house’s lightweight sheeting materials.

Preparing to blow a manufactured house roof

✓ Reinforce weak areas in the ceiling.
✓ Inspect the ceiling and seal all penetrations.
✓ Take steps to maintain safe clearances between insulation and recessed light fixtures and ceiling fans.
✓ Assemble patching materials such as metal patches, roof cement, fiberglass mesh, sheet-metal screws, putty tape, and roof coating.
Blowing through the top

This procedure involves cutting large square holes. Each square hole provides access to two truss cavities. If the roof contains a strongback running the length of the roof, the holes should be centered over the strongback, which is usually near the center of the roof’s width. A strongback is a 1-by-4 or a 1-by-6, installed at a right angle to the trusses near their center point, to add strength to the roof structure.

1. Cut 10-inch square holes at the roof’s apex on top of every second truss. Each square hole permits access to two truss cavities.

2. Use a 2-inch or 2-\(1/2\)-inch diameter fill-tube. Insert the fill-tube and push it forcefully out toward the edge of the cavity.

3. Blow fiberglass insulation into each cavity.

4. Stuff the area under each square hole with a piece of unfaced fiberglass batt so that the finished roof patch will stand a little higher than the surrounding roof.

5. Patch the hole with a 14-inch-square piece of stiff galvanized steel, sealed with roof cement and screwed into the existing metal roof.

6. Cover the first patch with a second patch, consisting of an 18-inch-square piece of foil-faced butyl rubber.

This approach fills the critical edge area with insulation. The patches are easy to install if you have the right materials. However, weather can be a bigger problem than with blowing through the edge.
Blowing a manufactured house roof from the edge

This procedure requires scaffold to be performed safely and efficiently. Manufactured house metal roofs are usually fastened only at the edge, where the roof joins the wall.

1. Remove the screws from the metal j-rail at the roof edge. Also remove staples or other fasteners, and scrape off putty tape.

2. Pry the metal roof up far enough to insert a 2-inch-diameter, 10-to-14-foot-long rigid fill tube. (Two common choices include steel muffler pipe and aluminum irrigation pipe.)

3. Blow insulation through the fill-tube into the cavity. Turn down the air on the blowing machine when the tube is a couple feet from the roof edge, in order to avoid blowing insulation out through the opening in the roof edge. Or stop blowing a foot or two from the
edge, and stuff the last foot or two with unfaced fiberglass batts.

4. Fasten the roof edge back to the wall using galvanized roofing nails, a new metal j-rail, new putty tape, and larger screws. The ideal way to re-fasten the metal roof edge is with air-driven galvanized staples, which is the way most roof edges were attached originally.

Note that re-installation of the roof edge is the most important part of this procedure. Putty tape must be replaced and installed as it was originally. This usually involves installing one layer of putty tape under the metal roof and another between the metal roof edge and the j-rail.

The advantages of blowing through the edge is that if you have the right tools, including a powered stapler, this method can be very fast and doesn’t require cutting into the roof. The disadvantages of this procedure are that you need scaffolding and you can’t do it if the roof has a strongback.

**Blowing a manufactured house roof from indoors**

This procedure requires the drilling of straight rows of 3-inch or 4-inch holes and blowing insulation into the roof cavity through a fill tube.

1. Drill a 3-inch or 4-inch hole in an unseen location to discover whether the roof structure contains a strongback that would prevent blowing the roof cavity from a single row of holes.

2. Devise a way to drill a straight row of holes down the center of the ceiling. If a strongback exists, drill two rows of holes at the quarter points of the width of the ceiling.

3. Insert a flexible plastic fill tube into the cavity, and push it as far as possible toward the edge of the roof.

4. Fill the cavity with tightly packed fiberglass insulation.
The obvious advantage to this method is that you are indoors, out of the weather. The disadvantages include being indoors where you can make a mess—or worse, damage something. Care must be taken not to damage the holes so that the plastic hole covers won’t fit properly.

**Title.3.2 Manufactured house floor insulation**

Manufactured house floor insulation is a beneficial measure for cool climates. The original insulation is usually fastened to the bottom of the floor joists, leaving the cavity uninsulated and subject to convection currents. This greatly reduces the insulation’s R-value.

**Blowing bellies:** A flexible fill tube, which is significantly stiffer than the blower hose, blows fiberglass insulation through a hole in the belly from underneath the home.

**Preparing for manufactured house floor insulation**

Prior to installing floor insulation, always perform these repairs.

1. Repair plumbing leaks.
2. Tightly seal all holes in the floor.
3. Inspect and seal ducts.
4. Install a ground moisture barrier in the crawl space if possible.
Insulating the floor

Two methods of insulating manufactured house floors are common. The first is drilling through the 2-by-6 rim joist and blowing fiberglass through a rigid fill tube. The second is blowing fiberglass insulation through a flexible fill tube from holes in the underbelly. Blown fiberglass is recommended over cellulose. Cellulose settling will cause it to fall away from the underside of the floor.

Unfaced fiberglass batts may also be used to insulate floor sections where the insulation and belly are missing. The insulation may be supported by lath, twine, or insulation supports. See "Floor insulation" on page 194.

When blowing through holes from underneath the home, consider blowing through damaged areas before patching them.
**Title 4 Manufactured House Windows and Doors**

Replacing windows and doors is generally not cost-effective and should only be done if repairs cannot hold the window or door together any longer. New jalousie or awning type windows are not acceptable as replacements. Replacement windows with an emergency release are available, and one of these should be considered for bedrooms when replacing windows.

**Title 4.1 Manufactured House Storm Windows**

Interior storm windows are common in manufactured houses. These stationary interior storms serve awning and jalousie windows. Sliding interior storm windows pair with exterior sliding prime windows.

**Glass interior storms:** Traditional manufactured house storm windows have aluminum frames glazed with glass.

**Plastic storms:** Some newer storm-window designs use a lightweight aluminum frame and flexible or rigid plastic glazing.

![Diagram of storm windows with labels for gasket, spline, plastic film, foam, tape, clip, and aluminum frame.](image-url)
• Interior storm windows double the R-value of a single-pane window. They also reduce infiltration, especially in the case of leaky jalousie prime windows.

• Avoid replacing existing storm windows unless the existing storm windows cannot be re-glazed or repaired.

• With sliding primary windows, use a sliding storm window that slides from the same side as the primary window. Sliding storm windows stay in place and aren’t removed seasonally. They are therefore less likely to be lost or broken.

Title 4.2 Replacing manufactured house windows

Inspect condition of rough opening members before replacing windows. Replace deteriorated, weak or waterlogged framing members.

Prepare replacement window by lining the perimeter of the inner lip with \( \frac{1}{8} \)-inch thick putty tape. Caulk exterior window frame perimeter to wall after installing window.

Title 4.3 Manufactured house doors

Manufactured house doors come in two basic types: the manufactured house door and the house-type door. Manufactured
house doors swing outwardly, and house-type doors swing inwardly.

Door replacement is an allowable expense only when the existing door is damaged beyond repair and constitutes a severe air-leakage problem.

**Title.4.4 Manufactured house health and safety**

Several health and safety items should be considered when weatherizing manufactured houses. These are highlighted in the manufactured house audit job book.

- Exhaust fan inspection and maintenance
- Dryer vent inspection and upgrades
- Water heater inspection for draft, clearances, combustion air, and PT valve
- Pressure balancing of air distribution systems
A–1 APPENDICES

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<td>Multi-tip screwdriver</td>
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<tr>
<td>Inspection mirror</td>
<td>Needle nose pliers&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hand calculator</td>
<td>Tall lamp shade harps</td>
</tr>
<tr>
<td>Measuring Tape</td>
<td>Lamp socket extenders</td>
</tr>
<tr>
<td>Non-contact or ambient thermometer</td>
<td>Lightweight cotton gloves</td>
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<tr>
<td>Digital watt-hour meter w/3-prong adapter</td>
<td>Variety of CFL’s</td>
</tr>
<tr>
<td>Standard thermometer</td>
<td>WD-40&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>Condenser brushes</td>
<td>Ladder</td>
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<td>Vacuum cleaner</td>
<td>Energy Education material</td>
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<tr>
<td>Replacement refrigerator fact sheet</td>
<td></td>
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</table>

<sup>a</sup> For bending lamp harps to fit & for removing broken light bulb bases from light sockets to allow CFL replacement. First turn electricity off at panel box.

<sup>b</sup> For loosening & removing broken bulb bases from sockets to allow CFL replacement. First turn electricity off at panel box.
# Air Sealing and Insulating Tools

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<td>Fill tubes and hose fittings</td>
<td>Caulking guns</td>
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<td>Coveralls and gloves</td>
<td>Chisels: cold and wood</td>
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<tr>
<td>First-aid kit</td>
<td>Cleaning fluid and rags</td>
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<tr>
<td>Hard hat</td>
<td>End nippers</td>
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<tr>
<td>Respirators and filters</td>
<td>Flashlight</td>
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<td>Safety glasses</td>
<td>Hack saw and blades</td>
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<tr>
<td>Extension ladders, leveler, &amp; hooks</td>
<td>Hammers and wrecking bars</td>
</tr>
<tr>
<td>Portable lights</td>
<td>Hand saws</td>
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<td>Scaffold, planks, and handrail</td>
<td>Hand staplers</td>
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<td>Step ladders: 4, 6, &amp; 8 foot</td>
<td>Metal &amp; Vinyl-siding zip tools</td>
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<td>Circular saw with blades</td>
<td>Mirror</td>
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<td>Compressor and power stapler</td>
<td>Pliers: electrical &amp; slip-joint</td>
</tr>
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<td>Drill index with bits</td>
<td>Putty knives and scrapers</td>
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<tr>
<td>Drills, drivers, and bits</td>
<td>Putty warmer</td>
</tr>
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<td>Extension cords</td>
<td>Scratch awl and pin punches</td>
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<td>HEPA vacuum with attachments</td>
<td>Screw- and nut-driver bits</td>
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<td>Lead paint drill shroud</td>
<td>Screw drivers and nut drivers</td>
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<td>Reciprocating saw with blades</td>
<td>Squares: framing, combo, dry-wall</td>
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<td>Shop vacuum, hoses, attachments</td>
<td>Steel tape measures</td>
</tr>
<tr>
<td>Shop vacuum, hoses, attachments</td>
<td>Tin snips: hand and electric</td>
</tr>
</tbody>
</table>
# Auditing and Mechanical Tools

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<tr>
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<th>Item</th>
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<td>Coveralls and gloves</td>
<td>Adjustable wrenches</td>
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<tr>
<td>Safety glasses</td>
<td>Chisels: cold and wood</td>
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<tr>
<td>Blower door</td>
<td>Clipboard box, writing supplies, pencils</td>
</tr>
<tr>
<td>Digital manometer with hoses</td>
<td>Flash lights and portable lights</td>
</tr>
<tr>
<td>Pressure pan</td>
<td>Flexduct strap tightener</td>
</tr>
<tr>
<td>Heat-exchanger test kit</td>
<td>Hack saw and blades</td>
</tr>
<tr>
<td>Digital combustion analyzer</td>
<td>Hand truck</td>
</tr>
<tr>
<td>Digital CO detector</td>
<td>Inspection mirror</td>
</tr>
<tr>
<td>Digital thermometer with ýT</td>
<td>Pipe wrenches</td>
</tr>
<tr>
<td>Moisture meter</td>
<td>Pliers: electrical &amp; slip-joint</td>
</tr>
<tr>
<td>Remote viewer</td>
<td>Screw and nut driver bits</td>
</tr>
<tr>
<td>Non-contact voltage detector</td>
<td>Screw and nut drivers</td>
</tr>
<tr>
<td>Volt-ohmmeter</td>
<td>Screw drivers and nut drivers</td>
</tr>
<tr>
<td>Digital wattmeter</td>
<td>Sheet-metal crimper</td>
</tr>
<tr>
<td>Plug-in circuit tester</td>
<td>Sockets and ratchet</td>
</tr>
<tr>
<td>Calculator</td>
<td>Steel tape measures</td>
</tr>
<tr>
<td>Auditing software</td>
<td>Tin snips</td>
</tr>
<tr>
<td>Cordless drill-driver</td>
<td>Wire and bristle brushes</td>
</tr>
<tr>
<td>Drill index with bits</td>
<td>Wire strippers</td>
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</tbody>
</table>
**Weatherization Materials and Inventory**

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<tr>
<th>Weatherization Materials</th>
<th>Additional Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>Assorted wire nuts and electrical connectors</td>
</tr>
<tr>
<td>Closed-cell foam tape</td>
<td>Compact fluorescent lamps</td>
</tr>
<tr>
<td>Fiberglass batts</td>
<td>Energy-saving shower heads</td>
</tr>
<tr>
<td>Fiberglass blowing wool</td>
<td>Programmable thermostats</td>
</tr>
<tr>
<td>Fiberglass duct wrap</td>
<td>Replacement fan controls</td>
</tr>
<tr>
<td>Foam backer rod</td>
<td>Replacement furnaces</td>
</tr>
<tr>
<td>Foam pipe sleeves</td>
<td>Replacement refrigerators</td>
</tr>
<tr>
<td>One-part squirt foam</td>
<td>Replacement water heaters</td>
</tr>
<tr>
<td>Sheet foam insulation</td>
<td>1/4-inch plywood or hardboard</td>
</tr>
<tr>
<td>Two-part spray foam</td>
<td>Assorted lumber</td>
</tr>
<tr>
<td>Water heater insulation</td>
<td>Assorted screws and nails</td>
</tr>
<tr>
<td>Assorted chimney pipe</td>
<td>Assorted staples</td>
</tr>
<tr>
<td>Assorted furnace filters</td>
<td>Construction adhesive</td>
</tr>
<tr>
<td>Duct mastic and web tape</td>
<td>Disposable coveralls, boot covers, and gloves</td>
</tr>
<tr>
<td>Duct tape and electrical tape</td>
<td>Disposable paint brushes</td>
</tr>
<tr>
<td>Furnace filter material</td>
<td>Plastic garbage bags</td>
</tr>
<tr>
<td>Proper vents</td>
<td>Plastic sheeting</td>
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<tr>
<td>Sheet metal</td>
<td>Pop riveter</td>
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<tr>
<td>Acoustical sealant</td>
<td>Putty tape</td>
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<td>Bronze v-seal weatherstrip</td>
<td>Silicone or urethane caulk</td>
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<td>Jamb-up weatherstrip</td>
<td>Siliconized acrylic-latex caulk</td>
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<td>Client-education booklets</td>
<td>Portable tape recorder</td>
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### Approximate R-values for Construction Materials

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<thead>
<tr>
<th>Material</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass or rock wool batts and blown 1”</td>
<td>2.8–4.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Blown cellulose 1”</td>
<td>3.0–4.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vermiculite loose fill 1”</td>
<td>2.7</td>
</tr>
<tr>
<td>White expanded polystyrene foam (beadboard) 1”</td>
<td>3.9–4.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Polyurethane/polyisocyanurate foam 1”</td>
<td>6.2–7.0&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>Extruded polystyrene (blue, yellow or pink) 1”</td>
<td>5.0</td>
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<tr>
<td>Oriented strand board (OSB) or plywood 1/2”</td>
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</tr>
<tr>
<td>Concrete 1”</td>
<td>0.1</td>
</tr>
<tr>
<td>Wood 1”</td>
<td>1.0&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fired clay bricks 1”</td>
<td>0.1–0.4</td>
</tr>
<tr>
<td>Gypsum or plasterboard 1/2”</td>
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<td>Single pane glass</td>
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<tr>
<td>Low-e insulated glass</td>
<td>3.3–4.2&lt;sup&gt;e&lt;/sup&gt;</td>
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<tr>
<td>Triple glazed glass with 2 low-e coatings</td>
<td>8.3</td>
</tr>
</tbody>
</table>

<sup>a</sup> Varies according to density (increases with increasing density).
<sup>b</sup> Varies according to density (decreases with increasing density).
<sup>c</sup> Varies according to age and formulation.
<sup>d</sup> Varies by species.
<sup>e</sup> Varies according to Solar Heat Gain Coefficient (SHGC) rating.
## COMPARISON OF VARIOUS UNITS OF PRESSURE

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### Efficiency Table for #2 Fuel Oil

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<th>350°</th>
<th>400°</th>
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<th>500°</th>
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<th>600°</th>
<th>CO₂%</th>
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RESOURCES


Weatherization Glossary

Absolute Humidity - AH: Air moisture content expressed in grains (or pounds) of water vapor per pound of dry air.

Absorptance: The ratio of a solar energy absorbed to incident solar. Also called absorptivity.

Absorption: A solid material's ability to draw in and hold liquid or gas.

Accent Lighting: Accent lighting illuminates walls, reduces brightness and contrast between walls and ceilings or windows.

Adsorption: Adhesion of a thin layer of molecules to a surface they contact.

Air Barrier: Any part of the building shell that offers resistance to air leakage. The air barrier is effective if it stops most air leakage. The primary air barrier is the most effective of a series of air barriers.

Air Changes per Hour at 50 Pascals - ACH: The number of times the volume of air in a structure will change in one hour at the induced blower door house pressure of 50 pascals.

Air Exchange: The total building air exchanged with the outdoors through air leakage and ventilation.

Air Handler: A steel cabinet containing a blower with cooling and/or heating coils connected to ducts that transports indoor air to and from the air handler.

Air Infiltration Barrier: A woven plastic sheet that stops almost all air traveling through a building cavity, while allowing moisture to pass through the cavity.

Air Sealing: Also known as “house doctoring,” air sealing is a systematic approach to “tightening” a dwelling unit's heated envelope (building shell) to reduce uncontrolled heat loss through air leakage points present in the shell. The prevalent technique is to perform this tightening from the interior of the home. Trained workers seal the air leakage points using a variety
of materials, such as insulation, caulk, foam, vapor barriers, and weather-strip. Air leakage identification is usually aided by using diagnostic equipment like blower doors and infrared scanners, since many leakage points are not obvious to the naked eye. Part of the air sealing protocol includes testing to ensure that the building envelope is not sealed too tightly. Over-tightening can result in health and safety problems for the occupants, including back drafting of combustion equipment (furnaces, hot water heaters) and moisture condensation causing mold and mildew on surfaces.

*Ambient lighting*: Lighting spread throughout the lighted space for safety, security, and aesthetics.

*American Society for Testing and Materials*: ASTM

*American Society of Heating, Refrigeration, and Air Conditioning Engineers*: ASHRAE

*American Wire Gauge*: AWG

*Ampere - A, Amp*: A unit of measure for the flow of electric current

*Annual Fuel Utilization Efficiency - AFUE*: A laboratory-derived efficiency for heating appliances that accounts for chimney losses, jacket losses, and cycling losses, but not distribution losses or fan/pump energy.

*Annual Return*: The yearly savings divided by the initial cost needed to achieve the savings, expressed as a percent.

*Aquastat*: A heating control device that controls the burner or the circulator in a hydronic heating system

*Asbestos*: A material made of sharp mineral fibers that damage lung and other bodily tissues.

*Attic Insulation*: The installation of approved insulation products (rockwool, fiberglass, and cellulose) evenly across the unconditioned attic area to achieve desired levels of thermal resistance. Insulation products have manufacturer rated “R” values (resistance to heat loss measurements). The more inches of
insulation installed the higher the resistance level. The recommended “R” values vary by climatic regions of the country. It is common for weatherization programs to install a minimum of R-19 or as much as R-38 in colder regions. The cost-effective level of insulation to be added, if any, depends on the existing level of insulation in the attic. Auditors determined the amount of insulation to be added through prescriptive lists or energy audit programs that calculate the saving to investment ratio from increasing insulation levels.

**Attic Preparation:** This refers to the protocol for inspecting and preparing an attic area for the installation of insulation. The preparatory work is directed primarily to air infiltration and safety issues. Some of the protocols include placing barriers around heat-producing sources in the attic (electrical junction boxes, recessed lights, etc.); placing chutes by the eaves to prevent the insulation from blocking needed air ventilation paths; and sealing bypasses and other penetrations between the heated space and the unconditioned attic area.

**Audit:** The process of identifying energy conservation opportunities in buildings.

**Back-drafting:** Continuous spillage of combustion gases from a combustion appliances

**Back-draft Damper:** A damper, installed near a fan, that allows air to flow in only one direction.

**Backer Rod:** Polyethylene foam rope used as a backer for caulking.

**Baffle:** A plate or strip designed to retard or redirect the flow of flue gases.

**Balance point:** The outdoor temperature at which no heating is needed.

**Balance Heating:** This is the result of balancing the airflow of the central heating distribution system so that intake and output air exists at levels to maximize efficiency. The balancing of the distribution system assures that all areas of the home being served
by the same heating or cooling system or any zone within the system receive approximately equal heated or cooled air.

**Ballast**: A coil of wire or electronic device that provides a high starting voltage for a lamp and limits the current flowing through it

**Band Joist**: See -Rim Joist

**Batt**: A narrow blanket of fiberglass insulation, generally 14.5" or 22.5" wide.

**Beam**: A strong horizontal building support used to carry the weight of a floor or roof.

**Bimetal Element**: A metal spring, lever, or disc made of two dissimilar metals that expand and contract at different rates as the temperature around them changes. This movement operates a switch in the control circuit of a heating or cooling device.

**Blower Door**: A blower door is a diagnostic tool used to locate the points of infiltration in the building envelope and help prioritize the air sealing protocols. This device can be mounted in an exterior door or window opening. The blower door uses a calibrated, powerful, variable speed fan to pressurize or depressurize the dwelling. Its adjustable frame allows the fan assembly to fit snugly in most frames. Air movement and pressure differentials are measured using a set of gauges attached to the frame and fan. These calculations of air movement allow technician to quantify the level of leakage. Such leakage measurements are usually expressed in terms of equivalent leakage area (ELA), air changes per hour (ACH), and cubic feet per minute of airflow (CFM). Anyone or more of these measurements can help determine levels of air leakage, indoor air quality, and amount of sealing work to be performed. In addition to measuring air movement, the blower door will exaggerate the leakage points in the building shell for easy identification. This diagnostic tool, when used in conjunction with an infrared scanner, produces even more accurate results.
**Blow-Down**: The act of removing water from a boiler to remove sediment and suspended particles.

**Blower Fan**: The squirrel-cage fan in a furnace or air handler.

**Boiler**: A fossil fuel appliance used for producing hot water or steam as the medium to distribute heat to the dwelling unit.

**Boot**: A duct section that connects between a duct and a register or between round and square ducts

**Branch Circuit**: An electrical circuit used to power outlets and lights within a home.

**Brightness**: The intensity of the sensation derived from viewing a lit surface. Measured in footlamberts, it is also called luminance or luminous intensity.

**British Thermal Unit - Btu**: The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

**Building Cavities**: The spaces inside walls, floors, and ceilings between the interior and exterior sheeting

**Building Envelope**: The area of the building that encloses conditioned space. Only the exterior four walls to the ceiling under the attic and the floor above the unheated basement area are considered part of the building envelope. The floor of a unit that is built on stilts or is above an unheated crawl space is considered a part of the building envelope. The roof of a building that has no ceilings (or that is part of the ceiling) is considered part of the building envelope.

**Building Science**: Branch of science dealing with construction, maintenance, safety, and energy efficiency of buildings.

**Burner**: A device that facilitates the burning of a fossil fuel, like gas or oil.

**Carbon Dioxide - CO2**: One of two main products of complete combustion of a hydrocarbon (the other is water vapor).
Carbon Monoxide - CO: Carbon Monoxide is a tasteless, odorless, colorless and poisonous gas that is a by-product of incomplete combustion of fossil fuels. It is usually caused by a lack of air to support combustion or impingement of the flame.

Casing: Exposed molding or trim around a window or door.

Caulking: Mastic compound for filling joints and cracks.

Cellulose Insulation: Insulation, packaged in bags for blowing, made from newspaper or wood waste and treated with a fire retardant.

Centigrade - C °: A temperature scale on which water freezes at 0 degrees and boils at 100 degrees.

Central Heating System: This refers to the primary heating system of the dwelling unit including the heat producing appliance, the return and supply system for heat distribution, and ducts or pipes for flue gas ventilation. Central heating systems usually do not include wood stoves, kerosene heaters, space heaters, and electric baseboard heating units.

CFM - Cubic Feet per Minute: A measurement of air movement past a certain point or through a certain structure. Usually seen as CFM 50, cubic feet per minute of air movement due to 50 pascal house/outdoor pressure differential.

CFM50 - Cubic Feet per Minute @ 50Pa.: This term means the amount of cubic feet per minute of air moving through a structure and measured at 50 pascal pressure.

CFMn - Cubic Feet per Minute Natural: The cubic feet of air flowing through a house from indoors to outdoors during typical, natural conditions. This figure can be roughly estimated using a blower door.

CFM Per Person or Per Room: An estimate of the cubic feet per minute of fresh air available or required per occupant or per room.
**Circuit Breaker**: A device found in a Circuit Panel Box that completes an electric circuit. This breaker disconnects the circuit from electricity when it senses an overload of current.

**Clean and Tune - C&T**: A procedure performed on a heating system by a licensed furnace service technician to maximize the appliance efficiency using existing hardware. The C&T is usually preceded by a combustion efficiency test to assess whether other conditions exist requiring extensive furnace work. The C&T can involve a variety of activities to upgrade the efficiency and safe operation of the heating system. These can include pilot and burner adjustment, adjustment of ventilation and combustion, check and reset controls, inspect filters, lubricate motors, flush low water cut-off, check operation of steam and water relief valves, check thermostat, check safety valve, and check thermocouple.

**Co-efficient of Performance - COP**: A heat pump or air conditioner's output in watt-hours of heat moved divided by watt-hours of electrical input.

**Coil**: A snake-like piece of copper tubing surrounded by rows of aluminum fins that clamp tightly to the tubing and aid in heat transfer.

**Color Rendering Index - CRI**: A measurement of a light source's ability to render colors the same as sunlight. CRI has a scale of 0 to 100.

**Color Temperature**: A measurement of the warmness or coolness of a light source in the Kelvin temperature scale.

**Column**: A vertical building support usually made of wood or steel.

**Combustible**: Means something will burn, although not necessarily readily.

**Combustion Air**: Air that chemically combines with a fuel during the combustion process to produce heat and flue gases, mainly carbon dioxide and water vapor.
**Combustion Analyzer**: A device used to measure steady-state efficiency of combustion heating units.

**Combustion Chamber**: The area inside the heat exchanger where the flame burns

**Combustion Test**: This test is performed to determine the efficiency at which a heating appliance is operating at steady state. The actual tests or sequence of tests may vary in conjunction with the type of testing equipment used or the type of heating appliance being tested. Persons performing these tests must be extremely familiar with the testing equipment being used and must be trained in conducting the tests. In some states, a license is required to perform such tests.

**Compressor**: A motorized pump that compresses the gaseous refrigerant and sends it to the condenser where heat is released.

**Condensate**: Vapor condensed back to a liquid.

**Condensate Receiver**: A tank for catching returning condensate water from a steam heating system.

**Condense**: When a gas turns into a liquid as it cools, it condenses. Condensation is the opposite of evaporation. When a gas condenses into a liquid it releases heat.

**Condenser**: The coil in an air conditioning system where the refrigerant condenses and releases heat, that is carried away by air moving through the coil.

**Conditioned**: Intentionally heated or cooled areas of a building

**Conductance**: The property of a material to conduct some energy form like heat or electricity.

**Conduction**: Conduction is the transfer of heat through a material by molecular movement. Reducing heat loss through conduction can include the installation insulation in wall, ceiling, and floor cavities, insulation of hot water tanks, creating thermal breaks in window and door framing, and sealing of bypasses and other sources of air movement.
**Contrast**: Difference in brightness measured by the relationship between an object’s brightness and the brightness of its background.

**Control Circuit**: A circuit whose work is switching a power circuit or opening an automatic valve.

**Convection**: The transfer of heat caused by the movement of a fluid like water or air. When a fluid becomes warmer it becomes lighter and rises.

**Convective Air Flow**: Air movement where less dense (warmer) air is displaced by more dense (cooler) air. Often expressed by the phrase “hot air rises.” Convective air flow can be useful if controlled, as in gravity hot air heating systems, but is more often a contributor to heat loss.

**Convective loop**: A structural heat loss resulting from temperature differences between the inside and outside wall surfaces causing an air movement loop within the wall cavity. This condition can be present when a stud cavity has no insulation. Air in the cavity is heated near the interior surface of the wall, rises, circulates back toward the exterior siding, falls, re-circulates back to the warm side, is re-heated, and so on.

**Cooling Load**: The maximum rate of heat removal required of an air conditioner when the outdoor temperature and humidity are at the highest expected level.

**Cost Effective**: Having an acceptable payback, return-on-investment, or savings-to-investment ratio.

**Cross Section**: A view of a building component drawn or imagined by cutting through the component.

**Community Services Block Grant - CSBG**: The Community Services Block Grant (CSBG) is federal, anti-poverty block grant which funds the operations of a state-administered network of local agencies. This CSBG network consists of more than 1,100
agencies that create, coordinate and deliver programs and services to low-income Americans in 96% of the nation’s counties.

Most agencies in the CSBG network are Community Action Agencies (CAAs), created through the Economic Opportunity Act, a predecessor of the CSBG. Community representation and accountability are hallmarks of the CSBG network, where agencies are governed by a tri-partite board. This structure consists of elected public officials, representatives of the low-income community, and appointed leaders from the private sector. Because the CSBG funds the central management and core activities of these agencies, the CSBG network is able to mobilize additional resources to combat the central causes of poverty.

*Curtain Wall*: A wall between columns and beams that supports no weight but its own

*Customer Certification*: A final determination concerning program eligibility based on income and ownership, resulting in the customer’s receipt or denial of WAP benefits.

*Dado*: A rectangular groove cut into wood.

*Decking*: The wood material installed under roofing material to support the roofing.

*Demand for Energy - Charge*: The peak need for electrical energy. Some utilities levy a monthly charge for demand.

*Demand Side Management - DSM*: The planning and implementation of those utility sponsored activities designed to influence customer use of electricity or gas in ways that will produce desired changes in the utility’s load shape, such as changes in the pattern and magnitude of the utility’s load. DSM study has resulted in a variety of utility-sponsored programs to redirect their customer’s usage patterns, especially in the peak load periods. While mainly an electric utility applied concept, there is some application to gas utilities as well. The ultimate goal for most utilities is to avoid the need to invest in new power plants or distribution due to excessive demands on current capacity.
**Density**: The weight of a material divided by its volume, usually measured in pounds per cubic foot.

**Degree Days**: A measure of the temperature element of climate produced by multiplying temperature difference by time.

**Depressurize**: Cause to have a lower pressure or vacuum with respect to a reference of a higher pressure.

**Desiccant**: A liquid or solid material used to absorb water or water vapor.

**Design Temperature**: A high or low temperature used for designing heating and cooling systems.

**Dew Point**: The warmest temperature of an object in an environment where water condensation from the surrounding air would form on that object.

**Dilution Air**: Air that enters through the dilution device—an opening where the chimney joins to an atmospheric-draft combustion appliance.

**Dilution Device**: A draft diverter or barometric draft control on an atmospheric-draft combustion appliance.

**Distribution System**: This term refers to that part of a central heating system used to deliver heated transfer media to the living space, and return the cooled transfer media to the appliance for re-heating. In a forced air system this includes the blower, ducts, registers, dampers, and cold air returns. In a hot water system this includes circulators, supply lines, radiators, and return lines.

**DOE**: Department of Energy

**Domestic Hot Water (DHW)**: Refers to a separate, closed system to heat potable (drinkable) water and supply it to the dwelling unit for washing, bathing, etc.

**Dormer**: A vertical window projecting from a roof.
Draft Diverter: A device located in gas appliance flue pipe. Used to moderate or divert draft that could extinguish the pilot or interfere with combustion.

Drywall: Gypsum interior wallboard used to produce a smooth and level interior wall surface and to resist fire. Also called gypsum wall board or sheetrock.

Dry Bulb Temperature: Normal ambient air temperature measured by a thermometer.

Duct Blower: A blower-door-like device used for testing duct leakiness and air flow.

Duplex: Any structure which consists of two separate dwelling units in one building.

Dwelling Unit: A house, including a stationary manufactured home, an apartment, a group of rooms, or a single room occupied as separate living quarters.

Eaves: The edges of a roof system (See -Soffit)

Efficiency: The ratio of output divided by input

Efficacy: The number of lumens produced by a watt used for lighting a lamp. Used to describe lighting efficiency.

Eligible Multi-Family Dwelling Units: A multi-family building qualifies to be weatherized in its entirety when 66% (50% for 2 and 4 unit buildings) or more of the total dwelling units in the building are determined to be eligible as per DOE rules.

Eligible Unit: A unit occupied by a household that is categorically eligible or income eligible by DOE and/or LIHEAP standards.

Emittance: The ability of a material to emit radiant energy from its surface. Also called emissivity.

Energy: A quantity of heat or work
Energy Consumption: The conversion or transformation of potential energy into kinetic energy for heat, light, electricity, etc.

Energy Education: The process used by WAP staff to inform customers of the ways they can further reduce energy consumption through altering their behavioral patterns. The most effective protocol includes multiple interaction and reinforcement with the household residents and use of a negotiated and written action plan.

Energy Efficiency: Term used to describe how efficiently a building component uses energy.

Energy Efficiency Ratio - EER: A measurement of energy efficiency for room air conditioners. The EER is computed by dividing cooling capacity, measured in British Thermal Units per hour (Btuh), by the watts of power. (See -Seasonal Energy Efficiency Rating or SEER)

Enthalpy: The internal heat of a material measured in Btus per pound.

Entropy: Heat unavailable to a closed thermodynamic system during a heat transfer process.

Environmental Protection Agency - U.S. EPA: EPA’s mission is to protect human health and to safeguard the natural environment - air, water, and land - upon which life depends. For 30 years, EPA has been working for a cleaner, healthier environment for the American people.

Equivalent Leakage Area (ELA): Calculation, in square inches, of the total area of all holes and cracks in a structure. The leakage area is then accumulated to represent one total leakage point.

Evaporation: The change that occurs when a liquid becomes a gas. Evaporation is the key process in the operation of air conditioners and evaporative coolers.
**Evaporative Cooler**: A device for cooling homes in dry climates by humidifying and cooling incoming air.

**Evaporator**: The heat transfer coil of an air conditioner or heat pump that cools the surrounding air as the refrigerant inside the coil evaporates and absorbs heat.

**Exfiltration**: This term describes the movement of air out of a building. Often refers to warm air leaving a building due to pressurization, infiltration, wind, stack effect, and/or convective flow.

**Fahrenheit - °F**: A temperature scale used in the United States and a few other countries. On the Fahrenheit scale, water boils at 212 degrees and freezes at 32 degrees.

**Family Unit**: All persons living together in a dwelling unit

**Fan Control**: A bimetal thermostat that turns the furnace blower on and off as it senses the presence of heat.

**Federal Energy Management Program - FEMP**: A program of DOE that implements energy legislation and presidential directives. FEMP provides project financing, technical guidance and assistance, coordination and reporting, and new initiatives for the federal government. It also helps federal agencies identify the best technologies and technology demonstrations for their use.

**Fenestration**: Window and door openings in a building's wall.

**Fiberglass**: A fibrous material made by spinning molten glass used as an insulator and heat loss retardant.

**Fill Tube**: A plastic or metal tube used for its stiffness to blow insulation inside a building cavity.

**Fin Comb**: A comb-like tool used to straighten bent fins in air conditioning coils.

**Fire Stop**: Framing member designed to stop the spread of fire within a wall cavity.
**Flame Safety Control**: A control device used to stop the flow of fuel to the burner assembly in the event of no ignition.

**Flashing**: Waterproof material used to prevent leakage at intersections between the roof surface at walls or penetrations.

**Floor Joists**: The framing members that support the floor area.

**Flue**: The channel of pipe used to control air flow of combustion gases.

**Foam Board**: Plastic foam insulation manufactured most commonly in 4’x8’ sheets in thickness of $\frac{1}{4}''$ to 3”.

**Foot Candle**: A measure of light striking a surface

**Footer**: The part of a foundation system that actually transfers the weight of the building to the ground

**Frost Line**: The maximum depth of the soil where water will freeze during the coldest weather

**Furnace**: An appliance for heating a medium to distribute heat throughout the dwelling unit.

**Gable**: The triangular section of an end wall formed by the pitch of the roof.

**Gas Heating System**: A heating system that uses natural gas or bottled liquid propane gas as fuel.

**Gasket**: Elastic strip that seals a joint between two materials.

**Glazing**: Glass installation. Pertaining to glass assemblies or windows

**Glass Load Factor**: A number combining glass's solar heat transmission and its heat conduction. Used for cooling load calculations.

**Gravity Furnace**: A central heating system that uses natural gravity to distribute heat throughout the dwelling unit as opposed to forced circulation, pumps, or circulation blowers.

**Gusset**: A metal or wood plate added to the surface of a joint to strengthen the connection.
Gypsum Board: A common interior sheeting material for walls and ceilings made of gypsum rock powder packaged between two sheets of heavy building paper. Also called sheetrock, gyprock, or gypboard.

Handicapped Person: Any individual who is: 1) handicapped as defined in Section 7 (6) of the Rehabilitation Act of 1973; 2) under a disability as defined in Section 1614 (1) (3) (A) or 223 (d) (i) of the Developmental Disabilities Services and Facilities Construction Act; or 3) who is receiving benefits under Chapter 11 or 15 of Title 38, U.S.C. Other conditions may apply state to state, which can deem an individual as handicapped for the purposes of the WAP.

Heat Anticipator: A very small electric heater in a thermostat that causes the thermostat to turn off before room temperature reaches the thermostat setting, so that the house does not overheat from heat remaining in the furnace and ducts after the burner shuts off.

Heat Capacity: The quantity of heat required to raise the temperature of 1 cubic foot of a material 1 degree F.

Heat Gains: Term used to mean unwanted heat that accumulates in homes, making mechanical cooling desirable or necessary.

Heat Loss: The amount of heat escaping through the building shell as measured for a specific period of time (month, year, etc.)

Heat Transmission: Heat flow through the walls, floor, and ceiling of a building, not including air leakage.

Heat Transfer Coefficient: See U-value.

Heating Degree Day - HDD): Each degree that the average daily temperature is below the base temperature (usually 65 degrees F) constitutes one heating degree day. Used to determine indoor space heating requirements and heating system sizing. Total HDD is the cumulative total for the year/heating season. The
higher the HDD for a location, the colder the daily average temperature(s).

*Heating Load*: The maximum rate of heat conversion needed by a building during the very coldest weather.

*Heating Seasonal Performance Factor - HSPF*: Rating for heat pumps describing how many Btus they transfer per kilowatt-hour of electricity consumed.

*Home Energy Rating Systems*: A nationally recognized energy rating program that give builders, mortgage lenders, secondary lending markets, homeowners, sellers, and buyers a precise evaluation of energy losing deficiencies in homes. Builders can use this system to gauge the energy quality in their home and also to have a star rating on their home to compare to other similarly built homes.

*Heating, Ventilation, and Air-Conditioning System - HVAC*: All components of the appliances used to condition interior air of a building.

*High Limit*: A bimetal thermostat that turns the heating element of a furnace off if it senses a dangerously high temperature.

*Home Heating Index*: The number of Btus of energy used by a home divided by its area in square feet, then divided by the number of heating degree days during the time period.

*HOME Program*: A program created under Title II (the Home Investment Partnership Act) of the National Affordable Housing Act of 1990. Provides funds for states to expand the supply of decent and affordable housing for low-income people. This program can be easily coordinated with a state's WAP efforts.

*Household*: Any individual or group of individuals who are living together as one economic unit for whom residential energy is customarily purchased in common or who make undesignated payments for energy in the form of rent.

*House Pressure*: The difference in pressure between the indoors and outdoors measured by a manometer.
HUD: U.S. Department of Urban Housing and Development

Humidistat: An automatic control that switches a fan, humidifier, or dehumidifier on and off to control relative humidity.

Humidity Ratio: Same as “absolute humidity.” The absolute amount of air's humidity measured in pounds of water vapor per pound of dry air.

Hydronic: A heating system that uses hot water or steam as the heat-transfer fluid.

Indoor Air Quality - IAQ: The quality of Indoor air relative to its acceptability for healthful human habitation. Assessing and ameliorating, when necessary, the quality of indoor air is a major concern of the weatherization process. In particular, all by-products of major combustion appliances must be directly evacuated to the outdoors under all operating conditions.

Illumination: The light level measured on a horizontal plane in Foot Candles

Inch of Water: Small air pressure differences caused by wind, blower doors, furnace fans, and chimneys are measured in inches of water (in.-H20) in the American measurement system.

Incidental Repairs: Under DOE rules, this term refers to the repairs on a dwelling unit necessary for the effective performance or preservation of the allowable energy conservation measures to be installed. Usually, a specific dollar amount is set by a state to limit such incidental repairs.

Indoor Air Quality - IAQ: Refers to the measurement of air quality in the living space of the home. Pollutants can exist within a home, and WAP staff must be aware of the impact their work has on the quality of the atmosphere within the living space. The presence of pollutants, combined with inadequate ventilation factors, can contribute to a variety of occupant health and safety problems. Therefore, IAQ is a primary concern when workers seal or “tighten” homes.
In-Kind Contributions: In-kind contributions represent the value of non-cash contributions provided by the grantee, and non-Federal parties. In-kind contributions may be in the form of charges for real property and non-expendable personal property and the value of goods and services directly benefiting and specifically identifiable to the project or program.

Infiltration: Infiltration refers to the movement of air into a building through cracks and penetrations in the building envelope. Cold air often enters the structure due to depressurization, exfiltration, wind, stack effect, and/or convective airflow.

Infrared Thermography: The science of using infrared imaging to detect radiant energy or heat loss characteristics of a building. The infrared camera or scanner electronically senses heat radiated by objects and converts that thermal energy into images visible to the human eye. The camera or scanner, similar to a camcorder in appearance, produces varying shades of black and white images of the building structure. The darker the image, the colder the corresponding surface; the lighter areas are the hotter surfaces. Some scanners can automatically record these images on video, as well as allow the operator to record audio commentary as he/she scans the building. A certain degree of interpretation skill is required to properly assess the images being recorded. Used in conjunction with a blower door, the scanner can provide valuable data, since the pressurization or depressurization can magnify air leakage sites and thermal bypasses.

Input Rating: The measured and assigned rating indicating the level at which an energy-using device consumes electricity or fossil fuel.

Insolation: The amount of solar radiation striking a surface

Insulated Glass: Two or more glass panes installed in windows and doors, spaced apart and sealed in a factory.
Internal Gains: The heat generated by bathing, cooking, and operating appliances, that must be removed during the summer to promote comfort.

Intermittent Ignition Device: A device that lights the pilot on a gas appliance when the control system calls for heat, thus saving the energy wasted by a standing pilot.

Intermediate Zone: A zone located between the building's conditioned space and the outdoors, like a crawl space or attic.

Jamb: The side or top piece of a window or door frame.

Joist: A horizontal wood framing member that supports a floor or ceiling.

Kilowatt - KW: A unit of electric power equal to 1000 joules per second or 3412 Btus per hour.

Kilowatt-hour - KWH: A unit of electric energy equal to 3600 kilojoules.

Landlord/Tenant Agreement: Document required for completed application when applicant is a renter. The Agreement is legally binding contract, signed by the tenant, the landlord (or property owner), and the local agency specifying the role and responsibilities of each party. The basic goal of the WAP is to ensure that the benefits of the program accrue to the low-income family. A variety of standard clauses can be incorporated into the Agreement, including clauses on landlord's inability to raise rents for specified period of time, eviction prohibition, and landlord required “participation.” Participation can take the form of actual cash, provided labor, and/or in-kind contributions.

Leakage Ratio: Measurement of total square inches of infiltration area per 100 feet of building envelope surface area.

Leverage Activity: The actions of the state and local agencies to obtain and account for resources provided to supplement or supplant federal funding being used to weatherize dwelling units.
**Local Agency**: Also referred to as the subgrantee, contractor, service delivery network member, or local service provider, a local agency is a nonprofit organization or unit of local government responsible for providing WAP services in a specified political subdivision.

**Low-E**: Short for “low emissivity”, which means the characteristic of a metallic glass coating to resist the flow of radiant heat.

**Low Water Cutoff**: A float-operated control for turning the burner off if a steam boiler is low on water.

**Lumen**: A unit of light output from a lamp.

**Make-up Air**: Air supplied to a space to replace exhausted air.

**Manometer**: Measuring device for small gas pressures.

**Manufactured Home Energy Audit - MHEA**: A software tool that predicts manufactured home energy consumption and recommends weatherization retrofit measures.

**Mastic**: A thick creamy substance used to seal seams and cracks in building materials.

**Mitigate**: To make less severe or to mollify.

**Mortar**: A mixture of sand, water, and cement used to bond bricks, stones, or blocks together.

**Mortise**: A recessed area cut into the wood framing member where a hinge or wood tongue fits.

**NASCSP National Association for State Community Services Programs**: NASCSP's mission is to assist state in responding to poverty issues. NASCSP members are state administrators of the Community Services Block Grant (CSBG) and U.S. Department of Energy's Weatherization Assistance Program (DOE/WAP). The CSBG, administered by the states, provides core funding to local agencies to reduce poverty, revitalize low-income communities and to empower low-income families to become self-sufficient. The DOE/WAP helps low-income families reduce their energy costs by making homes more energy efficient. The local
agencies funded by these programs provide a wide range of services such as weatherization, energy assistance, child care, job training, and housing. NASCSP keeps its members, the federal government, and other interested parties informed about issues related to CSBG and DOE/WAP through its publications.

*Natural Ventilation*: Ventilation using only natural air movement without fans or other mechanical devices.

*NEAT - National Energy Audit*: Created by Oak Ridge National Laboratories as a DOE approved audit qualifying for the 40% materials waiver. It is a computerized auditing tool for prioritizing energy conservation measures for houses.

*Net Free Area*: The area of a vent after that area has been adjusted for insect screen, louvers, and weather covering. The free area is always less than the actual area.

*Nozzle*: An orifice for spraying a liquid like fuel oil.

*Oil Heating System*: Refers to a central heating system that uses #2 fuel oil, kerosene, or residual oil as the primary fuel for heat generation.

*Open-Combustion Heater*: A heating device that takes its combustion air from the surrounding room air.

*Orifice*: A hole in a gas pipe or nozzle fitting where gas or fuel oil exits to be mixed with air before combustion occurs in the heating chamber.

*Oscillating Fan*: A fan, usually portable, that moves back and forth as it operates, changing the direction of the air movement.

*Output Capacity*: The conversion rate of useful heat that a heating unit produces after accounting for any waste caused by the conversion of energy into heat.

*Oxygen Depletion Sensor*: A safety device on a heating unit that shuts off the fuel supply to the combustion chamber when oxygen is depleted.
Packaged Air Conditioner: An air conditioner that contains the compressor, evaporator, and condenser in a single cabinet.

PA - Pascal: A unit of measurement of air pressure. One column inch of water equals 247 pascals. Atmospheric pressure (29.92 inches of mercury) is equivalent to 102,000 PA.

Payback Period: The number of years that an investment in energy conservation will take to repay its cost through energy savings.

Perlite: A heat-expanded mineral used for insulation.

Perm: A measurement of how much water vapor a material will let pass through it per unit of time.

Plaster: A plastic mixture of sand, lime, and Portland cement spread over wood or metal lath to form the interior surfaces of walls and ceilings.

Plate: A piece of lumber installed horizontally to which the vertical studs in a wall frame are attached.

Plenum: The piece of ductwork, usually found above the heat exchanger of a hot air furnace, that connects the air handler to the main supply duct.

Plumb: Absolutely vertical at a right angle to the earth’s surface.

Plywood: Laminated wood sheeting with layers cross-grained to each other.

Polyethylene: Polymer plastic used for vapor barriers, air barriers, and foam backer rod.

Polyisocyanurate: A plastic foam insulation sold in sheets, similar in composition to polyurethane.

Polystyrene Insulation: A rigid plastic foam insulation, usually white or blue in color.

Polyurethane: A versatile plastic foam insulation, usually yellow in color.
**Potential Energy** : Energy in a stored or packaged form, like fuel oil, coal, wood, etc.

**Pressure** : A force encouraging movement by virtue of a difference in some condition between two areas.

**Pressure Diagnostics** : The practice of measuring pressures and flows in buildings to control air leakage, and also to ensure adequate heating and cooling air flows and ventilation.

**Pressure Pan** : A device used to block a duct register while measuring the static pressure behind it.

**Pressuretrol** : A control that turns a steam boiler's burner on and off as steam pressure changes.

**Prime Window** : The main window installed on the outside wall consisting of fixed or moveable lights that slide on permanently fixed tracks (not to be confused with a storm window).

**Priority list** : The list or ranking of installation measures developed by a program to produce the most cost effective energy savings results based on a savings to investment ratio calculation.

**Program Income**: Income earned by the grantee from grant-supported activities, including but not limited to, income from service fees, sale of commodities, usage or rental fees, and royalties on patents and copyrights.

**Psychrometrics** : The study of the relationship between air, water vapor, and heat.

**Purlins** : Framing members that sit on top of rafters, perpendicular to them, designed to spread support to roofing materials.

**PV -Photovoltaic** : A solid-state electrical device that converts light directly into direct current electricity of voltage-current characteristics that are a function of the characteristics of the light source and the materials in and design of the device. Solar photovoltaic devices are made of various semi-conductor materials including silicon, cadmium sulfide, cadmium telluride, and
gallium arsenide, and in single crystalline, multi-crystalline, or amorphous forms.

**R-Value**: A measurement of thermal resistance for materials and related surfaces.

**Radiant Barrier**: A foil sheet or coating designed to reflect heat producing sun rays.

**Radiant Temperature**: The average reflective temperature of objects in a home, like walls, ceiling, floor, and furniture.

**Radiation**: Heat energy originating on a hot body like the sun and traveling from place to place through the air.

**Radon**: A radioactive gas that decomposes into radioactive particles.

**Rafter**: A roof beam that follows the roofs slope.

**Reflectance**: Also called reflectivity, it is the ability of a material's surface to reflect radiant heat.

**Recovery Efficiency**: A water heater's efficiency at actually heating water to capacity level without regard to standby or distribution losses.

**Reflective Glass**: Glass that has a mirror-like coating on its exterior surface to reflect solar heat. The solar heat gain coefficient of reflective glass ranges from 0.10 to OAO.

**Refrigerant**: A special fluid used in air conditioners and heat pumps that heats air when it condenses from a gas to a liquid and cools air when it evaporates from a liquid to a gas.

**Register**: The grille cover over a duct outlet for warm air distribution or cold air return.

**Relamping**: The replacement of an existing, standard light bulbs with lower wattage energy efficient bulbs like compact fluorescent lamps.
Relative Humidity: The percent of moisture absorbed in the air compared to the maximum amount possible. For instance, air that is completely saturated has 100% relative humidity.

Relay: An automatic, electrically-operated switch.

Reset Controller: Adjusts fluid temperature or pressure in a central heating system according to outdoor air temperature.

Resistance: The property of a material resisting the flow of electrical energy or heat energy.

Retrofit: An energy conservation measure applied to an existing building or the action of improving the thermal performance or maintenance of a building.

Return Air: Air circulation back to the furnace from the house to be heated by the furnace and supplied to the rooms.

Re-Weatherized Unit: Any unit that received weatherization services prior to September 30, 1985 and has received additional services under subsequent grants or allowed by current DOE regulations.

Rim Joist: The outermost joist around the perimeter of the floor framing.

Savings-to-Investment Ratio (SIR): They are computed over the lifetimes of the retrofit measures installed and expressed in terms of the net present value of the retail cost of the dwelling's fuel. Under some methodologies, other benefits, etc. Investment usually takes into account materials, labor, and support costs. SIRs of greater than one are counted as cost effective under this DOE WAP method of determining cost-effectiveness.

Sealed Combustion Heater: A heater that draws air for combustion from outdoors and has a sealed exhaust system.

Seasonal Efficiency: Refers to the overall efficiency of the central heating system including on and off cycle fuel utilization and heat loss. The calculation of these factors is represented in the Annual Fuel Utilization Efficiency (AFUE) rating for the appliance. Distribution system loss is not factored into the AFUE.
**Seasonal Energy Efficiency Ratio - SEER:** A measure of seasonal or annual efficiency of a central air conditioner or air conditioning heat pump. It takes into account the variations in temperature that can occur within a season and is the average number of Btu of cooling delivered for every watt-hour of electricity used by the heat pump over a cooling season.

**Seasonal Performance Factor - SPF:** Ratio of useful energy output of a device to the energy input, averaged over an entire heating season.

**Separate Living Quarters:** Living quarters in which the occupants do not live and eat with any other persons in the structure and that have either a direct access from the outside of the building or through a common hall or complete kitchen facilities for the exclusive use of the occupants. The occupants may be a single family, one person living alone, two or more families living together, or any other group of related or unrelated persons who share living arrangements.

**Sequencer:** A bimetal switch that turns on the elements of an electric furnace in sequence.

**Settling:** This term refers to the effect of insulation depressing over time and, thereby, reducing the overall energy efficiency of the materials. This process is primarily the result of using too much air when installing the blown-in insulation—commonly called “fluffing,” or the effect of long periods of time on the materials. One reason to reinspect some work several months after installation is to assess the settling factor. Settling can also occur during the installation of sidewall insulation when the cavity is not completely filled. This is usually avoided if “dense pack” protocols are followed during the installation.

**Shading Coefficient (SC):** A decimal describing how much solar energy is transmitted through a window opening compared to clear single glass having an SC of 1.0. For example, reflective glass has an SC of 0.20 to 0.45.
Sheathing: A structural sheeting, attached on top of the framing, underneath siding, or on the roof of a building.

Sheeting: Common term for any building material used for covering a building surface.

Shell: The building's exterior envelope including walls, floor, and roof.

Shingle: A modular roofing material, usually asphalt, that is installed in overlapping rows to cover the entire roof.

Short Circuit: A dangerous malfunction in an electrical circuit where electricity is flowing through conductors and into the ground without going through an electric load, like a light or motor.

Sidewall Insulation: The process of installing insulation material, usually blown cellulose, into the non-insulated wall stud cavities of a structure to reduce heat loss. Installation is achieved by drilling one or more rows of holes into the wall, one in each stud cavity. To achieve the most effective results, a dense pack protocol is used to install “high density” insulation materials. The “packing” of the materials should be tight enough that the installer cannot move the insulation when complete. It is common to install materials at 3.5 pounds per square foot.

Sill: The bottom of a window or door frame.

Sill Box: The outer area of the floor bound by the rim joist, floor joist, sill plate, and floor.

Sling Psychrometer: A device holding two thermometers that is slung through the air to measure relative humidity.

Soffit: The underside of a roof overhang or a small lowered ceiling, as above cabinets or a bathtub.

Solar Gain: Heat from the sun that is absorbed by a building’s materials and contributes to the heating and cooling requirements of the dwelling.
Solar Heat: Radiant energy from the sun with wavelengths between 0.7 and 1 micrometers.

Solar Heat Gain Coefficient - SHGC: The ratio of solar heat gain through a window to incident solar heat, including both transmitted heat and absorbed/radiated heat.

Solar Heat Gain Factor - SHGF: Solar heat gain amount on a surface with a particular angle and orientation expressed in Btus per square foot per hour.

Solar Transmittance: The percent of total solar energy transmitted by a material.

Solenoid: A magnetic device that moves a switch or valve stem.

Space Heating: Heating the living spaces of the home with a room heater or central heating system.

Span: Horizontal distance between supports.

Specific Heat: The ratio of the heat storage capacity of a particular material to the heat storage capacity of water.

Spillage: Temporary flow of combustion gases from a dilution device.

Spline: A strip of vinyl, rubber, or plastic that, when inserted into a groove, holds a screen or plastic film in place on a frame.

Split-System Air Conditioner: An air conditioner having the condenser and compressor outdoors and the evaporator indoors.

Stack Effect: The term describes the effect of higher pressure at the top of a structure, lower pressure at the bottom of a structure, and neutral pressure somewhere in between, relative to the ambient (surrounding) air pressure. It is usually the result of different densities of warmer and cooler air (convective airflow).

Standing Loss: Heat loss from a hot water storage tank through its shell.
**Steady State Efficiency**: The measurement of heat system balance in the on-cycle when heat into system equals heat out. Generally provided as a percentage of the maximum available heat generation capacity (100%) against the amount of usable heat being sent to the distribution system. This figure can also represent the percentage of heat being used within the system as compared to the heat lost through the flue. The reading is most valid when the stack temperature becomes constant and the distribution pumps or blowers are operating.

**Steam Trap**: An automatic valve that closes to trap steam in a radiator until it condenses.

**Steam Vent**: A bimetal-operated air vent that allows air to leave steam piping and radiators, but closes when steam strikes the surface.

**Stop**: A thin, trim board for windows and doors to close against or slide against.

**Strike Plate**: The metal plate attached to the door jamb that the latch inserts into upon closing.

**Stud**: A vertical wood or metal framing member used to build a wall.

**Sub-Floor**: The sheathing over the floor joists and under the floor covering.

**Supply Air**: Air that has been heated or cooled and is moved through the ducts and to the supply registers of a home.

**Suspended Ceiling**: Modular ceiling panels supported by a hanging frame.

**Taped Duct Test -TDT**: A procedure using the blower door to measure the “potential” for leakage reduction of the duct system. All supply registers and return grills are taped shut following the initial blower door reading and a subsequent air leakage test taken. If closing off the duct system in this manner causes an appreciable reduction in the air leakage rate, this is an indication that there are significant duct leaks.
Temperature Rise: The number of degrees of temperature increase that air is heated as it is blown over the heat exchanger. Temperature Rise equals supply temperature minus return temperature.

Therm: A unit of energy equal to 100,000 Btus or 29.3 kilowatt-hours.

Thermal Break: A relatively low heat/cold conductive material separating two highly conductive materials.

Thermal Bridging: Rapid heat conduction resulting from direct contact between very thermally conductive materials like metal and glass.

Thermal Bypass: Similar to a convection loop, this structural heat loss is characterized by heated air traveling up exterior or interior stud cavities and leaking out the top of that cavity to the attic through joints and cracks in the framing, wiring and plumbing holes, etc. These types of heat loss sources are sometimes the most difficult to locate.

Thermal Conductance: General term applied to both K-value and U-value, meaning heat flow rate.

Thermocouple: A bimetal-junction electric generator used to keep the safety valve of an automatic gas valve open.

Thermodynamics: The science of heat.

Title XVI: Term to be used interchangeably with those income groups known as SSI (Supplemental Security Income) recipients.

Tracer Gas: A harmless gas used to measure air leakage in a building.

Transformer: A double coil of wire that increases or decreases voltage from a primary circuit to a secondary circuit.

Trim: Decorative wood that covers cracks around window and door openings and at the corners where walls meet floors and ceilings. Sometimes called molding.
Truss: A lightweight, rigid framework designed to be stronger than a solid beam of the same weight.

U-Value: The amount of heat flowing through a square foot of building materials.

Ultraviolet Radiation: Solar radiation having wavelengths just shorter than visible light.

Unconditioned Space: An area within the building envelope not intentionally or unintentionally heated.

Vapor Barrier: A material that retards the passage of water vapor.

Vapor Diffusion: The flow of water vapor through a solid material.

Veiling Reflection: Light reflection from an object or task that obscures details.

Veneer: The outer layer of a building component (e.g., interior doors often have a wood veneer; some wood-frame houses have brick veneer walls, etc.).

Vent Connector: The vent pipe carrying combustion gases from the appliance to the chimney.

Vent Damper: An automatic damper powered by heat or electricity that closes the chimney while a heating device is off.

Venting: The removal of combustion gases by a chimney.

Ventilation: Refers to the controlled air exchange within a structure. All dwellings must “breathe” and proper ventilation rates must be determined. If the structure requires more interior/exterior air exchanges, there are mechanical and non-mechanical options for increasing those rates. The most common option is passive ventilation through the installation of roof, soffit, or gable vents.

Vermiculite: A heat-expanded mineral used for insulation.
Visible Transmittance: The percent of visible light transmitted by a glass assembly.

Visqueen: Polyethylene film vapor barrier.

Watt: A unit electrical power equivalent to one joule per second or 3.4 Btuh

Watt-Hour: A unit of electrical energy equivalent to 3600 joules or 3.4 Btus.

Weatherization Assistance Program - WAP: DOE’s Weatherization Assistance Program is the nation’s largest residential energy efficiency program. Its mission is to increase the energy efficiency of dwellings occupied by low-income Americans, thereby reducing their energy costs, while safeguarding their health and safety.

DOE works directly with the states, the District of Columbia, and Native American Tribal Governments to carry out these goals. These agencies, in turn, contract with approximately 1,000 local governmental or non-profit agencies to deliver weatherization services to our low-income clients.

Weatherstripping: Flexible gaskets, often mounted in rigid metal strips, for limiting air leakage at opening in the shell like doors and windows.

Webbing: A reinforcing fabric used with mastics and coatings to prevent patches from cracking.

Weep Holes: Holes drilled for the purpose of allowing water to drain out of an area in a building where it has accumulated.

Wet-Bulb Temperature: The temperature of a dampened thermometer of a Sling Psychrometer used to determine relative humidity, dew point, and enthalpy.

Window Films: Plastic films, coated with a metallic reflective surface, that are adhered to window glass to reflect heat rays from the sun.
Window Frame: The sides, top, and sill of the window forming a box around window sashes and other components.

Worst-Case Depressurization Test: A safety test, performed by specific procedures, designed to assess the probability of chimney back-drafting.

Zone: A room or portion of a building separated from other rooms by an air barrier.
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